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Grand Junction Projects Office Facility
Grand Junction Projects Office Remedial Action Project
Monticello Mill Tailings Site

Environmental Monitoring Plan

Work performed under DOE Contract No. DE–AC04–86ID12584 for the **U.S. Department of Energy**
Grand Junction Projects Office

Chem-Nuclear Geotech, Inc.

OU111 AR 560

GRAND JUNCTION PROJECTS OFFICE FACILITY,

GRAND JUNCTION PROJECTS OFFICE
REMEDIAL ACTION PROJECT,

AND THE MONTICELLO MILL TAILINGS SITE

ENVIRONMENTAL MONITORING PLAN

Chem-Nuclear Geotech, Inc.
Grand Junction, Colorado

Prepared for the
U.S. Department of Energy
Grand Junction Projects Office
Under DOE Contract No. DE-AC07-86ID12584

560A

RUST GEOTECH INC.

MEMO TO: Distribution

FROM: D. L. Langdon

DATE: November 2, 1994

SUBJECT: Annual Review of the Environmental Monitoring Plan (P-GJPO-109)

An annual review of the *Grand Junction Projects Office Facility, Grand Junction Projects Office Remedial Action Project, and the Monticello Mill Tailings Site Environmental Monitoring Plan* (EMP), as required by DOE Order 5400., was conducted during October 1994. Attached are the resultant revisions, which address only changes identified since the 1993 annual review. Both the 1993 and 1994 revisions will be used to update the EMP in 1995.

Please insert the 1994 revisions before the 1993 revisions at the front of your document. If you have questions, please call P.R. Engelder at Extension 6553 or me at Extension 6562.

pre/kdp
Attachments

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Environmental Monitoring Plan
Annual Review

November 1994

The *Grand Junction Projects Office Facility, Grand Junction Projects Office Remedial Action Project, and the Monticello Mill Tailings Site Environmental Monitoring Plan* (EMP) was completed on November 9, 1991, in accordance with U.S. Department of Energy (DOE) Order 5400.1 (Chapter IV, Section 4). The order requires that the EMP be reviewed annually and updated every 3 years. Because of the numerous changes in the Grand Junction Projects Office's (GJPO's) environmental monitoring programs during 1992, an update of the EMP was prepared and distributed on November 9, 1992. This year (November 1994), an annual review of the EMP was conducted. The attached revisions (and those from 1993) identify the sections and contents of the EMP that will be amended during the next update, scheduled to be completed by November 9, 1995. Up-to-date descriptions of the field and laboratory procedures used for collecting and analyzing samples of environmental media are in several documents supporting the EMP: the *Sampling and Analysis Plan for Environmental Monitoring*; the *Monticello Mill Tailings Site and Proposed Repository, Monitoring of Air Particulate, Radon, and Gamma Radiation Emissions Work Plan*; the *Monticello Mill Tailings Site, Operable Unit III, Surface- and Ground-Water Remedial Investigation/Feasibility Study Field Sampling Plan*; and the *Monticello Mill Tailings Site MSGRAP Directive*s *MSGRAP-94-01* and *MSGRAP-94-02*.

Revisions

Section 1.0, Introduction

Section 1.2 (Pages 1-2 and 1-3): This section will be rewritten to reflect a restatement of the data quality objectives to conform with the seven step method outlined in the *Data Quality Objectives Process for Superfund Workbook* (EPA, 1993). These data quality objectives will document the approach currently used by Environmental Sciences in its monitoring activities and couple it with a quantification of the uncertainty in the data.

Figure 1-3 (Page 1-10): The words "Proposed Permanent Repository Site for Mill Tailings" and the "No Access Permitted" area will be deleted.

Figure 1-4 (Page 1-11): The words "Proposed Permanent Repository Site for Mill Tailings" will be deleted.

Figure 3-4 (Page 3-26): The symbol designating W-5 will be changed, because it is not currently an active sampling location; the three new upgradient seeps, Pehrson 1, Pehrson 2, and Upper North Drainage, will be added; and the reference to the South Site as the permanent repository will be removed.

Section 3.2.3.1, last ¶ (Page 3-28) and References Section): The references Rust Geotech Inc. 1993b and 1994b will be included in this section and in the list of references.

Table 3-10 (Page 3-30): This table will be replaced by the attached Table 3-10 and renumbered as appropriate.

Section 4.0, Ground Water

Section 4.2.2.2.1, 7th ¶ (Page 4-14): This paragraph will be rewritten to reflect the completion of remediation and the changes in ground water quality observed in 1994.

Section 4.2.2.2.2, 1st ¶ (Page 4-15): Changes will be made in the text where appropriate to show that Well 1-9SA will be included in 9-month sampling events.

Table 4-6 (Page 4-15): Table 4-6 will be replaced (attached).

Figure 4-1 (Page 4-16): The symbol for well 1-9SA will be changed to show that the well is currently monitored. Wells 14-13NB, 13-16NA, and 13-16NB, which have been abandoned, will be removed.

Section 4.2.3.1 3rd ¶ (Page 4-19): This section will be rewritten to describe current sampling. References to specific years will be deleted.

Figure 4-2 (Page 4-20): The reference to the South Site as the proposed permanent repository site will be deleted. The figure will be changed to show that well 93-01 was installed at the former location of well 84-77 (from which the casing was pulled) and that well 36SE93-201-2 is included in the monitoring.

Figure 4-3 (Page 4-21): This figure will be changed to show that well 84-74 has been abandoned and that well 36NE93-205 is included in the monitoring.

Section 4.2.3.2.2, 1st ¶ (Page 4-22): Upon approval by the EPA and state of Utah, twenty-six wells will be sampled; samples collected in April from one upgradient well, three millsite wells, and one downgradient well (the exact wells will be selected prior to the sampling event) will be analyzed for organics. This section will be modified to reflect these changes.

Section 5.1.2.2.2 (Page 5-10): The first five paragraphs will be deleted. The section will start with "Emission sampling ..."

Table 5-3 (Page 5-10): This table will be deleted.

Figure 5-2 (Page 5-11): This figure will be deleted.

Section 5.1.2.2.2, Last ¶ (Page 5-12): The first sentence of this paragraph will be rewritten as: "To comply with the requirements of state emissions permits, opacity monitoring of the Analytical Chemistry Laboratory and Boiler Plant will be conducted quarterly.

Section 5.1.2.2.4, 1st ¶ (Page 5-12): The 4th sentence, "Air effluent data will be reported..." will be deleted. The last sentence will be rewritten as: "A summary of the data will be presented in the Annual Site Environmental Report."

Section 5.1.3 (Page 5-13): This section will be deleted.

Section 5.2 (Pages 5-13 through 5-22): Section 5.2 will be deleted, because no air surveillance monitoring is conducted; the remaining sections of this chapter will be renumbered accordingly.

Section 5.2.1 and Section 5.2.2 (Page 5-13): These sections will be deleted.

Table 5.4 (Pages 5-14 and 5-15): This table will be deleted.

Section 5.2.3.1, 3rd ¶ (Page 5-16): The paragraph "Meteorological wind-rose..." will be deleted.

Section 5.2.3.1, 4th ¶ (Page 5-16): The first sentence will be rewritten as: "Historically, the network of three samplers ran every sixth day for 24 hours."

Section 5.2.3.1 5th ¶ (Page 5-16): The following paragraph will be inserted after the paragraph that begins "In January 1992...": In October 1993, the air particulate monitoring program was revised again. Two PM_{10} samplers and seven low-volume samplers were added to the network. The PM_{10} samplers were added to more adequately monitor dust levels; the low-volume samplers, which run continuously, were added to serve as dedicated radioparticulate samplers (Figure 5-3).

Section 5.2.3.1, last ¶ (Page 5-16): The last paragraph will be replaced with: The environmental radon monitoring program was initiated in Monticello in 1984. Detectors were exposed in duplicate 1 meter above the ground at the locations shown in Figure 5-4. The number of samples was reduced from 19 to 8 in 1985, then increased to 15 in 1994. Annual average radon concentrations have been consistent from year to year, indicating a constant rate of radon emissions from the piles. Radon levels at monitoring

Section 6.2.2.2 through 6.2.2.3 (Pages 6-1 and 6-4): Because there are no plans for monitoring environmental radiation at the GJPO facility in the future, this section will be deleted. Table 6-1 on page 6-2 will remain.

Figure 6-1 (Page 6-2): This figure will be deleted.

Section 6.2.3.1, 1st ¶ (Page 6-5): The following sentence will be added to the end of the paragraph that starts with "The direct environmental radiation program for the MMTS...": Seven locations were added in October 1993 to better define the gamma radiation. In an attempt to improve measurement accuracy, two TLDs were installed at each location instead of one.

Section 6.2.3.2.2, 1st ¶ (Page 6-5): The number in the second sentence of the paragraph starting with "The direct environmental radiation program will continue..." will be changed from 13 to 20. The last sentence in this paragraph, "New TLDs...," will be deleted.

Figure 6-2 (Page 6-6): This figure will be renumbered as appropriate and modified to reflect seven new TLD monitoring locations. The reference to the South Site as a proposed permanent repository site for mill tailings and the area in which access is denied will be deleted.

Sections 6.2.3.2.3, 6.2.3.2.4, and 6.2.3.3 (Page 6-7): These sections will be expanded to include the appropriate text from the corresponding paragraphs in Section 6.2.2.2 and 6.2.2.3 that are being deleted.

Section 7.0, Biota

This section will be replaced (attached).

Section 8.0, Reclamation

This section will be added (attached).

Appendix A, Quality Assurance Program Plan

Appendix A will be revised (in progress).

Table 3-10a. Surface Water Sampling Locations, MMTS

Surface Sample	Location
Pehrson 1	Upgradient
Pehrson 2	Upgradient
SW92-01	Upgradient
SW92-02	Upgradient
SW92-03	Upgradient
Upper North Drainage	Upgradient
Carbonate Seep	Millsite
North Drainage	Millsite
SW92-04	Millsite
SW92-05	Millsite
W-2	Millsite
Montezuma Canyon	Downgradient
Sorenson	Downgradient
SW92-06	Downgradient
SW92-07	Downgradient
SW92-08	Downgradient
SW92-09	Downgradient
W-4	Downgradient

Table 3-10 (continued). Surface Water Quality Analytes, MMTS

Analytical Parameters	Analytes
Radionuclides	Radium-226 Radium-228 Thorium-230 Thorium-232 Uranium-234 Uranium-238 Radon-222

Table 4-7. Ground Water Quality Analytes, MMTS

Analytical Parameters	Analytes
Volatile Organic Compounds[a]	Target Compound List[b]
Semivolatile Organic Compounds[a]	Target Compound List[b]
Pesticides/PCBs[a]	Aldrin Alpha-BHC Beta-BHC Delta-BHC Gamma-BHC (lindane) Alpha-Chlordane Gamma-Chlordane 4,4'-DDD 4,4'-DDE 4,4'-DDT Dieldrin Endosulfan I Endosulfan II Endosulfan Sulfate Endrin Endrin Aldehyde Heptachlor Heptachlor Epoxide Methoxychlor Toxaphene Aroclor 1016 Aroclor 1221 Aroclor 1232 Aroclor 1242 Aroclor 1248 Aroclor 1254 Aroclor 1260

[a]Samples collected in April from five wells will be analyzed for volatiles, semivolatiles, pesticides, and herbicides .

[b]Target Compound List volatiles and semivolatiles are listed in the *Monticello Mill Tailings Site, Operable Unit III, Surface- and Ground- Water Remedial Investigation/ Feasibility Study Field Sampling Plan* (Chem-Nuclear Geotech, Inc. 1992c).

[c]Analyte measured only at well 31SW91-23.

Analytical Parameters	Analytes
Metals	Nickel Selenium Silver Thallium Vanadium Zinc
Total Dissolved Solids	TDS
Radionuclides	Gross Alpha Gross Beta Lead-210 Polonium-210 Radium-226 Radium-228 Thorium-230 Thorium-232 Uranium-234 Uranium-238 Radon-222

[a]Samples collected in April from five wells will be analyzed for volatiles, semi-volatiles, pesticides, and herbicides .

[b]Target Compound List volatiles and semivolatiles are listed in the *Monticello Mill Tailings Site, Operable Unit III, Surface- and Ground- Water Remedial Investigation/ Feasibility Study Field Sampling Plan* (Chem-Nuclear Geotech, Inc. 1992c).

[c]Analyte measured only at well 31SW91-23.

7.0 BIOTA

7.1 ENVIRONMENTAL SURVEILLANCE

7.1.1 Regulatory Requirements

Biota sampling for the GJPO/GJPORAP and MMTS complies with all ARARs listed in Table 7-1.

7.2. GJPO/GJPORAP

7.2.1 Historical Biota Sampling

Biota sampling was conducted at the GJPO facility between May and September, 1993. Carp, cottonwood, and native grasses were sampled from on-site and off-site locations. Details of the sampling effort are presented in the *Plan for Radiological Surveillance of Biota at the Grand Junction Projects Office Facility* (RUST Geotech Inc. 1993c), and *Radiological Surveillance of Biota at the Grand Junction Projects Office Facility* (RUST Geotech Inc. 1993d).

7.2.1.1 *Monitoring Objectives*

The objectives of the biota sampling were

1. to determine if significantly higher-than-background concentrations of radiological constituents exist within selected biota at or near the facility; and

2. to determine the potential radiation dose to native aquatic organisms at or near the GJPO facility to ensure compliance with the DOE dose limit of 1 rad/day.

7.2.2 Planned Biota Sampling

No additional sampling is planned at this time.

7.3 MMTS

7.3.1 Historical Biota Sampling

Qualitative surveys of aquatic ecosystems and terrestrial vegetation on and downstream of the millsite were conducted in 1988 (BIO/WEST, Inc. 1988; and Western Resource Development Corp. 1988, respectively).

7.3.2 Planned Biota Sampling Program

7.3.2.1 *Monitoring Objectives*

The objectives of the biota sampling are:

1. to collect data to support the OU III Ecological Risk Assessment; and

2. to determine the potential radiation dose to native aquatic organisms at or near the MMTS facility to ensure compliance with the DOE dose limit of 1 rad/day.

7.3.2.2 *Sampling Plan*

Biota sampling is planned for Operable Unit III of the MMTS. The study design will be presented in the revised OU III RI Work Plan, which will be completed in March 1995. Sampling is expected to begin in May 1995.

7.3.2.3 *Data Management*

The Data Manager, who is appointed by the Geotech Project Manager, will maintain a data base for the biota sampling data. Data will be stored on an ORACLE data base through the use of a DEC Alpha computer system. All records, reports, and data will be stored in a permanent project file in Geotech's Records Management Section.

7.3.2.4 *Data Analysis/Reporting Format*

The reporting format and data analysis method will be detailed in the Sampling Plan to be completed by March 1995.

7.4 Responsible Organizations

The biota sampling program is the responsibility of the DOE-GJPO Manager. The Geotech Program Manager directs the Geotech Project Manager with the appropriate expertise to complete the necessary requirements of the biota sampling program. The responsibility of the biota sampling program currently resides with the Environmental Services Section.

The following will added to the References section:

BIO/WEST, Inc. 1988. *An Aquatic Biology Survey of Montezuma Creek, Utah*, prepared for UNC Geotech, Grand Junction, CO.

Western Resource Development Corp. 1988. *Monticello Remedial Action Project Peripheral Properties Vegetation Survey, 1988, San Juan County, Utah*, prepared for UNC Geotech, Grand Junction, CO.

Environmental Monitoring Plan
Annual Review

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The *Grand Junction Projects Office Facility, Grand Junction Projects Office Remedial Action Project, and the Monticello Mill Tailings Site Environmental Monitoring Plan* (EMP) was completed on November 9, 1991, in accordance with U.S. Department of Energy (DOE) Order 5400.1 (Chapter IV, Section 4). The order requires that the EMP be reviewed annually and updated every 3 years. Because of the numerous changes in the Grand Junction Projects Office's (GJPO's) environmental monitoring programs during 1992, an update of the EMP was prepared and distributed on November 9, 1992. This year (November 1993), an annual review of the EMP was conducted. The following Revision Sheet identifies the sections and contents of the EMP that will be revised during the next update, which is scheduled to be completed by November 9, 1995. Up-to-date descriptions of the field and laboratory procedures used for collecting and analyzing samples of environmental media are in several documents supporting the EMP: the *Sampling and Analysis Plan for Environmental Monitoring*; the *Monticello Mill Tailings Site and Proposed Repository, Monitoring of Air Particulate, Radon, and Gamma Radiation Emissions Work Plan*; and the *Monticello Mill Tailings Site, Operable Unit III, Surface- and Ground-Water Remedial Investigation/Feasibility Study Field Sampling Plan*.

Revision Sheet

Section 1.0, Introduction

Section 1.1 (Page 1-2, 2nd Paragraph [¶]): The third sentence will be rewritten as follows: "Data from all four quarters will be summarized in an Annual Site Environmental Report, which will be sent to DOE-Albuquerque by June 1 of each calendar year."

Section 1.3.2 (Page 1-6, 4th ¶) and Figure 1-2: The text and figure regarding "areas remediated as of October 1992" and "areas of remaining radiological contamination" will be updated to reflect current conditions.

Section 1.3.2 (Page 1-6, last ¶): The third sentence will be rewritten to state that cleanup of the facility is overseen by the <u>Southwestern</u> Area Programs Division's D&D Branch, not the Northwestern Area.

Figure 1-3: The word "Repository" is misspelled and will be corrected.

Section 1.3.4 (Page 1-12, 4th ¶): Northwestern Area Programs Division will be changed to Southwestern Area Programs Division.

Section 1.3.4 (Page 1-13, 1st ¶): The permanent repository that will contain tailings removed from the millsite and Monticello area may not be located on the South Site. This paragraph will be updated to reflect current conditions.

Table 1-1 (Page 1-14): The word "Inhalation" will be added to the first column as "Radon Daughters (Inhalation);" the spelling of daughters will be corrected. The footnote will be expanded to read:

> NA = not applicable. The dose from direct external exposure is not applicable to the lung because it is an internal organ; the dose from radon daughters is not applicable to the whole body because alpha particles do not penetrate the skin.

In addition, the phrase "(excluding background)" will be added next to the heading "Enhanced Conditions."

Section 2.0, Meteorology

Figure 2-1: The location of the GJPO on-site meteorological monitoring station will be moved slightly to the south to a point inside the Leased Army Reserve Area.

Table 2-2.: A solar radiation instrument will no longer be part of the GJPO on-site meteorology station; reference to it will be deleted from this table. In addition, all Nova Lynx instruments will be replaced with Campbell Scientific equipment in November 1993. References to the Nova Lynx equipment throughout the text will be replaced with "Campbell Scientific" equipment.

Section 2.2.2.1 (page 2-6, last ¶): The MICROAIRDOS model will be replaced by the CAP88-PC model.

Table 2-3: A solar radiation instrument will no longer be part of the MMTS meteorology station; reference to it will be deleted from this table. Additionally, all Nova Lynx instruments will be replaced with Campbell Scientific equipment in November 1993 with the exception of the precipitation gauge, which will be replaced with NOAH equipment.

Section 3.0, Surface Water

Section 3.11 (Page 3-1) and Table 3-1: The City of Grand Junction/Mesa County Industrial Pretreatment Permit citation will be updated to reflect the new requirement of a quarterly monitoring program rather than a semiannual program.

Section 3.1.2.1 (Page 3-1) and 3.1.2.2.2 (Page 3-8): These sections will be updated to reflect DOE-GJPO's implementation of procedures required under the revised Industrial Pretreatment Permit (effective March 1, 1993). Current procedures and requirements of the permit are discussed in Chapter 7.0 of the *Sampling and Analysis Plan for Environmental Monitoring*. In general, quarterly reports are required to be submitted to the city by January 31, April 30, July 31, and October 31. Sewer effluent will be sampled quarterly from the North Lift Station (not Manhole #12) for the analytes listed in Table 3-4. In addition to the quarterly sampling for Table 3-4 constituents, a monthly flow-proportioned, composite sample will be collected and analyzed for gross alpha and gross beta, and a weekly grab sample will be collected for an instantaneous analysis of pH and temperature. Table 3-3, which contains the list of constituents measured within sewer effluent before the revised permit came into effect, will be deleted.

Figure 3-1: This figure will be updated to show the current sampling point for sewer effluent, which is located in the North Parking Lot.

Section 3.1.2.2.2 (Page 3-8, last ¶): The third sentence will be rewritten to state "Effluent will be sampled once a year, conditions permitting, and will be analyzed for the constituents listed in Table 3-5."

Table 3-5: Total uranium and radium-226 will be added to the list of constituents.

Section 3.2.2 (Page 3-12): The Dike Ditch sampling point no longer exists because the area was excavated and recountoured during remedial action. All references to the existence or future sampling of the Dike Ditch will be removed.

During remedial action, the South Pond was excavated to a depth such that it will contain water perennially, even during drought years. The appropriate sentence will be updated in the text.

Section 3.2.2.2.2 (Page 3-21, 1st ¶): Frequency of sampling of the four Gunnison River locations will remain quarterly; however, the North and South Ponds will be sampled on a 9-month schedule.

Figure 3-2: The Dike Ditch will be removed from the figure because it no longer exists.

Section 3.2.3.2.2 (Page 3-29) and Table 3-10: Upon approval by the EPA and state of Utah, several changes will occur in the MMTS surface water monitoring program. Sampling will be conducted semiannually rather than four times a year; and organics, selected metals, and other analytes will no longer be sampled for.

Figure 3-5: The W-4 sampling location will be moved slightly to the east; reference to the South Site as the permanent repository will be removed; and, the "No Access Permitted" area will be removed.

Section 4.0, Ground Water

Section 4.2.2 (Page 4-1, 3rd ¶): The reference to the *GJPO Ground Water Protection Management Plan* will be deleted.

4.2.2.2.1 (Page 4-10, last ¶): The first sentence will be rewritten as follows: "Present and future monitoring for the GJPO/GJPORAP will focus on constituents that do not presently meet federal and state standards and on constituents associated with uranium mill tailings contamination for which no standards exist (such as manganese and vanadium).

Table 4-3 (Page 4-11): Individual references to radium-226 and radium-228 will be deleted from the table, and a new reference to radium-226+228, with a maximum concentration value of 5 pCi/L, will be added.

Section 4.2.2.2.2 (Page 4-15) and Table 4-6: Well 1-9SA will no longer be sampled because samples analyzed from this well have not exceeded any standard for several years. All references to future sampling of this well will be removed.

Wells in and downgradient of the remaining area of contaminated soil (10-19N, GJ84-04, 13-16NA, 14-13NA, 11-12NA, and GJ87-15) will be sampled on a quarterly basis. Six wells upgradient of this area (GJ84-09, GJ84-10, 5-12NA, 8-4S, 14-6NA, and 11-1S) will be sampled on a nine-month basis.

Figure 4-1: The symbol for well 1-9SA will be changed to show that the well is not currently monitored. Well 14-6NB has been abandoned and will be removed from the figure.

Section 4.2.3 (Page 4-18, 3rd ¶): The reference to the *GJPO Ground Water Protection Management Plan* will be deleted.

Section 4.2.3.1 (Page 4-19, 4th ¶): The first sentence will be rewritten as follows: "Since 1979, more than 40 water quality parameters have been investigated."

Section 4.2.3.2.2 (Page 4-22) and Table 4-7: Upon approval by the EPA and state of Utah, several changes will occur in the MMTS ground water monitoring program. Sampling will be conducted semiannually rather than four times a year; organics, selected metals, and other analytes will no longer be sampled for; and, three fewer wells will be sampled.

Figure 4-2: The labels for wells 92-05 and 92-06 will be switched.

Figure 4-3: The labels for wells 92-11 and 92-12 will be switched; the label "Sorensen Site" will be deleted (this is a surface water sampling point); the reference to the South Site as the proposed permanent repository site will be deleted; and, the "No Access Permitted" area will be removed.

Section 5.0, Air

Section 5.1.2 (Page 5-1, 3rd ¶): The second sentence will be reworded as follows: "Air emission permits from the Colorado Department of Health, Air Pollution Control Division, have been obtained for the first three sources. As a condition of the permits, opacity from these sources shall not exceed 20 percent."

Tables 5-1 and 5-4 (Pages 5-2 and 5-14, last ¶): A portion of the last sentence under "Description" will be deleted; the sentence will state "The ability to detect, quantify, and adequately respond to unplanned releases of radioactive material to the environment relies on in-place effluent monitoring."

Section 5.1.2 (Page 5-7, first ¶): The last sentence, "With the HEPA filter installed, the air emissions permit requires only opacity monitoring of Petrology Laboratory emissions" will be deleted, because it is repetitive of an earlier statement.

Section 5.1.2.1 (Page 5-8, 3rd ¶): The last sentence will be rewritten as follows: "In January 1993, an emission monitoring port was installed in the Baghouse, and continuous sampling during Baghouse operation was begun."

Section 5.1.2.2.1 (Page 5-9, 5th ¶): The paragraph will be rewritten as follows: "State air emission permits for the Analytical Chemistry Laboratory, Boiler Plant, Petrology Laboratory, and Baghouse require that emissions not exceed 20 percent opacity."

Section 5.1.2.2.2 (Page 5-10, 2nd ¶): The last portion of the last sentence referring to the collection of radioparticulate filter blanks will be deleted because radioparticulate filter blanks will no longer be collected.

Section 5.1.2.2.2 (Page 5-12, 2nd ¶): The first sentence will be rewritten as follows: "Emission sampling of the Baghouse stack will be continuous during operation of the Baghouse at the location shown in Figure 5-1." The 4th sentence will be updated as follows: "Filters will be collected after approximately every 400 hours of Baghouse operation and will be analyzed by the Geotech Analytical Chemistry Laboratory..."

Section 5.1.2.2.2 (Page 5-12, 3rd ¶): The first sentence will be changed to reflect <u>quarterly</u> sampling for opacity rather than monthly. The last sentence will be changed to state "Observations will be recorded on a Colorado Department of Health form and stored in an Opacity Observation file by the Environmental Services Section of Geotech.

Section 5.1.2.2.3 (Page 5-12): The last sentence in this section will be deleted and the following added to the text: "Geotech Analytical Chemistry Laboratory reports for air monitoring will be centralized in a permanent project file in Geotech's Records Management Section. All other data collected under the air monitoring program will be stored in the Environmental Services Section of Geotech.

Sections 5.1.2.2.4 and 5.2.3.2.4 (Pages 5-12 and 5-21): The EPA-approved dose model MICROAIRDOS will be replaced by the CAP88-PC model.

Section 5.2.3.2.2 (Page 5-21, 1st ¶): The last portion of the sentence referring to the collection of radioparticulate filter blanks will be deleted because radioparticulate filter blanks will no longer be collected.

Section 6.0, Direct Environmental Radiation

Section 6.2.2.2.4 (Page 6-4): The phrase "within the GJPO Facility" in the last sentence of this section will be changed to "outside the GJPO Facility."

Section 7.0, Biota

Section 7.1: The following information will be incorporated into the text:

> The *Plan for Radiological Surveillance of Biota at the Grand Junction Projects Office Facility* was completed in April 1993. Biota sampling, in which cottonwood trees, grasses and forbs, and carp were sampled, occurred from May through September 1993. A final report will be completed by December 31, 1993.

Section 7.2: The last sentence in this section will be replaced by: "A draft plan to determine the ecological effects of MMTS-related contaminants in surface and ground water will be completed by January 1994."

Section 8.0, Quality Assurance

Page 8-1, last ¶: The first sentence will be deleted, and the second sentence will be rewritten as follows: "The Geotech Analytical Chemistry Laboratory maintains an internal QC organization to provide data review and verification and evaluation of QA data."

Appendix A, Quality Assurance Program Plan

Appendix A will be replace with the attached, revised Appendix A.

JAN 2 5 1993

GRAND JUNCTION PROJECTS OFFICE FACILITY
GRAND JUNCTION PROJECTS OFFICE
REMEDIAL ACTION PROJECT
MONTICELLO MILL TAILINGS SITE

ENVIRONMENTAL MONITORING PLAN

AL/EPD Reviewers: Shiv Goel

Karen S. McAda

Frank H. Sprague

Approved by:

Bruce G. Twining Date
Manager

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TABLES

ABBREVIATIONS AND ACRONYMS

ACL	Alternate Concentration Limit
ALARA	As Low As Reasonably Achievable
ARAR	Applicable or Relevant and Appropriate Requirement
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
AIC	Acceptable Intakes for Chronic Exposure
C	Centigrade
CAR	Corrective Action Request
$CaSO_4$:Dy	calcium sulfate dysprosium
CCR	Code of Colorado Regulations
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CRS	Colorado Revised Statutes
CSU	Colorado State University
DCG	Derived Concentration Guides
D&D	Decontamination and Decomissioning
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
DQO	Data Quality Objective
EA	Environmental Assessment
EDE	Effective Dose Equivalent
EH-1	Assistant Secretary for Environment, Safety, and Health, DOE Headquarters
EMP	Environmental Monitoring Plan
EPA	U.S. Environmental Protection Agency
FFA	Federal Facility Agreement
ft/day	feet per day
GJPO	Grand Junction Projects Office
GJPORAP	Grand Junction Projects Office Remedial Action Project
HEPA	High-Efficiency Particulate Air (filter)
Hg	Mercury
km	kilometer
mb	millibar
mg/L	Milligrams per liter
MMTS	Monticello Mill Tailings Site
MRAP	Monticello Remedial Action Project
MPH	Miles Per Hour
mrem	milliroentgen equivalent man
mR/hr	milliroentgens per hour
MSGRAP	Monticello Surface and Ground Water Remedial Action Project
NA	Not Applicable

NEPA	National Environmental Policy Act of 1969 (PL91-190)
NESHAPS	National Emission Standards for Hazardous Air Pollution
NPDES	National Pollutant Discharge Elimination System
NQA-1	Nuclear Quality Assurance
ORNL	Oak Ridge National Laboratory
PCB	Polychlorinated biphenyl
pCi/g	picocuries per gram
pCi/L	picocuries per liter
pH	hydrogen ion concentration
PM_{10}	particulate matter less than 10 micrometers in diameter
PSO	Program Senior Official
QA	Quality Assurance
QAI	Quality Assurance Instructions
QAMS	Quality Assurance Management Staff
QAP	Quality Assurance Program
QAPjP	Quality Assurance Project Plan
QAPP	Quality Assurance Program Plan
RCRA	Resource Conservation and Recovery Act
rem	roentgen equivalent man
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of Decision
SARA	Superfund Amendments and Reauthorization Act
SFMP	Surplus Facility Management Program
TCL	Target Compound List
T.D.	total depth
TLD	Thermoluminescent dosimeter
UAC	Utah Administrative Code
μCi/ml	microcuries per milliliter
$\mu g/m^3$	micrograms per cubic meter
μm	micrometer
UMTRCA	Uranium Mill Tailings Radiation Control Act

DEFINITIONS

Criterion When used in the Quality Assurance Program as a capitalized term, a statement of the application of one of the 18 Basic Requirements of NQA-1 to the kind of work performed or directed by Chem-Nuclear Geotech, Inc.

Data Quality Objectives describe the uncertainty that a decision maker is willing to accept in results derived from environmental data. This uncertainty is used to specify the quality of the measurement data required, usually in terms of accuracy, precision, completeness, representativeness, and comparability.

> Accuracy--the degree of agreement of a measurement with an accepted reference or true value, usually expressed as the difference or as a ratio between the two values. Accuracy is a measure of the bias in a system.
>
> Precision--a measure of mutual agreement among individual measurements of the same property, usually under prescribed similar conditions. Precision is most desirably expressed in terms of the standard deviation.
>
> Completeness--a measure of the amount of valid data obtained from a measurement system compared to the amount that was expected to be obtained under correct normal conditions.
>
> Representativeness--the degree to which data accurately and precisely represent a characteristic of a population, parameter variations at a sampling point, or an environmental condition.
>
> Comparability--a measure of the confidence with which one data set can be compared to another.

Environmental Monitoring is the collection and analysis of samples or direct measurements of environmental media. Environmental monitoring consists of two major activities: effluent monitoring and environmental surveillance.

> Effluent Monitoring--is the collection and analysis of samples, or measurements of liquid and gaseous effluents, for the purposes of characterizing and quantifying contaminants, assessing radiation exposures to members of the public, providing a means to control effluents at or near the point of discharge, and demonstrating compliance with applicable standards and permit requirements.
>
> Environmental Surveillance--is the collection and analysis of samples, or direct measurements of air, water, soil, foodstuff, biota, and other media, for the purposes of determining compliance with applicable standards and permit requirements, assessing radiation exposures of members of the public, and assessing the effects, if any, on the local environment.

Nonconformance is a deficiency in a characteristic, procedure, or documentation that renders the quality of an item unacceptable or indeterminate. Examples of nonconformances include, but are not limited to, physical defects, test failures, incorrect or inadequate documentation; deviations from prescribed processing, inspection, test procedures, or other technical requirements documents.

Quality Assurance (QA) includes all planned and systematic actions necessary to provide adequate confidence that a facility, structure, system, or component will perform satisfactorily in service. The goal of QA is to ensure (1) that research, development, demonstration, and production activities are performed in a controlled manner; (2) that components, systems, and processes are designed, developed, constructed, tested, operated, maintained, and decommissioned according to sound engineering standards, quality practices, and technical specifications; and (3) that the resulting technical data are valid and retrievable. QA includes quality control.

> QA Program Standard "S" Level--is a base QA program that applies to all Chem-Nuclear Geotech activities. Required reviews, inspections, assessments, verifications, and audits are applied to ensure that practices and procedures are adequate to provide quality.
>
> QA Program Quality "Q" Level--provides for the application of a higher level of QA requirements than those for the Standard Level. "Q" Level applies to all items and activities that will be used in regulatory licensing actions or that have a reasonable potential for becoming critical to the attainment of DOE programmatic objectives.

Quality Assurance Program Plan (QAPP) is a document identifying the requirements that the Program Manager and the QA Coordinator have judiciously selected from the overall QA Program, along with DOE's QA requirements that are to be imposed on a particular program. The QAPP provides an index or a description of the procedures that implement these QA requirements and other supplementary requirements. The QAPP also includes specific responsibilities and authorities for implementing the requirements it contains.

Quality Control (QC) are those quality actions necessary to control and verify the features and characteristics of an item, material, process, facility, or service to specified requirements.

1.0 Introduction

1.0 INTRODUCTION

1.1 OVERVIEW

This Environmental Monitoring Plan (EMP) has been prepared in compliance with U. S. Department of Energy (DOE) Order 5400.1, *General Environmental Protection Program*, which requires an EMP to be prepared for each site, facility, or process that uses, generates, releases, or manages significant pollutants or hazardous materials. The EMP addresses monitoring activities for the DOE Grand Junction Projects Office (GJPO) Facility, the DOE Grand Junction Projects Office Remedial Action Project (GJPORAP), and the DOE Monticello Mill Tailings Site (MMTS). Associated with the MMTS are two remedial action projects: the Monticello Remedial Action Project (MRAP) and the Monticello Surface and Ground Water Remedial Action Project (MSGRAP). All sites and projects are managed by the DOE-GJPO.

Many elements are contained within the EMP, including the rationale and design criteria for the monitoring programs, extent and frequency of monitoring and measurements, laboratory analysis procedures, quality assurance (QA) requirements, program implementation procedures, and direction for the preparation and disposition of reports. Section 1.0 (Introduction) describes the purpose of the EMP and the location of and general environmental conditions at each of the sites. Sections 2.0 through 7.0 present the individual environmental monitoring programs for Meteorology, Surface Water, Ground Water, Air, Direct Environmental Radiation, and Biota, respectively. Sections 3.0 through 6.0 are divided into subsections that describe effluent monitoring and environmental surveillance activities (see Definitions section). Within each subsection, the monitoring objectives, sampling/QA plans, data management responsibilities, data analysis techniques, and data reporting formats are presented. The organizations responsible for implementing the programs also are identified. Each monitoring program is carefully designed to comply with the requirements of local, state, and federal laws and regulations, and DOE orders. The Quality Assurance Program Plan (QAPP), which is applicable to all the monitoring programs, is described in Section 8.0 and in Appendix A. Section 9.0 contains a description of the Records Management policy for EMP activities.

Soils and pond/river sediments are not discussed in this EMP because they are not regularly monitored for the GJPO/GJPORAP and Monticello Millsite. In 1984, 1985, and 1989, radiological characterization surveys (Abramiuk and others 1984, Henwood and Ridolfi 1986, UNC Geotech 1990a) were conducted at the GJPO and Monticello Millsite. Soils were sampled and analyzed for radium-226, potassium-40, thorium-232, and delta-gamma exposure rates. From these analyses, contour maps delineating all areas containing radium-226 concentrations exceeding Uranium Mill Tailing Radiation Control Act (UMTRCA) standards (40 CFR 192.12) were generated. At the GJPO, the contaminated areas included sediments within the South Pond and Dike area along the Gunnison River (see Sections 1.2.2 and 3.2.2.1). Sediments within the Gunnison River had been sampled previously, in 1979 and 1980, and though radium-226 concentrations at that time were found to be higher than background, they were well below UMTRCA standards. At the Monticello Millsite, contaminated sediments with radiologic concentrations exceeding UMTRCA standards were found within Montezuma Creek (see Sections 1.2.4 and 3.2.3.1). The GJPORAP, MRAP, and MSGRAP were initiated, and are currently ongoing, to remove these and other contaminated materials on the site locations and surrounding areas. Upon completion of remedial action, both sites will be resurveyed to verify compliance with UMTRCA standards.

All data collected through the environmental monitoring program will be tabulated and reviewed on a quarterly basis. Environmental Monitoring Quarterly Reports will be prepared for the first three calendar quarters (January-March; April-June; and July-September). Data from all four quarters will be summarized in an Annual Site Environmental Report, which will be sent to DOE-Headquarters by June 1 of each calendar year. In addition to the summarization of environmental data, the annual report will include: (1) a characterization of the site environmental management performance, (2) a comparison of the monitoring data with established standards and regulations for compliance purposes, and (3) a description of the significant programs and efforts being implemented at the DOE facilities, such as those pertaining to site management inspections, waste management programs, Superfund Amendments and Reauthorization Act (SARA) Title III reporting, and pollution abatement projects. The report is available to all members of the public and is distributed to local, state, and federal officials and agencies who have an interest in site activities.

Selected data from the monitoring program will be used for updating other reports generated by the DOE-GJPO, such as the *Ground Water Protection Management Plan, Air Emissions Annual Report, Radioactive Effluent and On-Site Discharge Data Reports*, and the *Industrial Pretreatment Report* to the city of Grand Junction. These various reports will be prepared by Chem-Nuclear Geotech, Inc. (Geotech), Environmental Services Section, and submitted to DOE-GJPO for approval and off-site distribution.

Data gathered through the environmental monitoring programs will support the ALARA (As Low As Reasonably Achievable) Programs established for the GJPO and Monticello Millsite Facilities. These programs were established to ensure that radiation doses to individuals are maintained as far below the prescribed limits as is reasonable. Environmental monitoring of radiological sources will help determine whether ALARA goals are met.

Changes in monitoring strategies may occur in response to regulatory changes or to increases or decreases in ongoing remedial activities at the GJPO and Monticello Millsite Facilities. When these changes occur, the EMP will be updated. Revisions will be issued by the Manager of Environmental Services through the Records Management Section. At a minimum, the EMP will be reviewed annually and updated every 3 years.

Closely tied to this EMP is a supporting document titled, *Sampling and Analysis Plan for Environmental Monitoring* (P-GJPO-109.1) (Chem-Nuclear Geotech, Inc. 1992a). Whereas the EMP establishes the rationale and basic framework for environmental monitoring at the GJPO and MMTS, the latter document describes field and laboratory procedures for collecting and analyzing samples of environmental media. It provides details of the procedures that are introduced, but not fully discussed, in this document. Because the latter document will be updated each time a change in field or laboratory procedures occurs, it will likely contain more current information than the EMP. When referring to either document, one should carefully note the date of revision to ascertain which document contains the most up-to-date information.

Contained in the *Sampling and Analysis Plan for Environmental Monitoring* (Chem-Nuclear Geotech, Inc. 1992a) are procedures for sampling the Sample Preparation Facility exhaust stack, atmospheric radon, environmental radiation, air particulates, ground and surface waters, and sewer effluent at the GJPO Facility, and procedures for operating and calibrating meteorological stations at the GJPO Facility and MMTS. Procedures for sampling environmental media (radon, environmental radiation, air particulates, ground water, and surface water) at the MMTS are discussed in separate, controlled documents. The draft *Monticello Mill Tailings Site and Proposed Repository, Monitoring of Air Particulate, Radon, and Gamma Radiation Emissions Work Plan* (Chem-Nuclear Geotech, Inc. 1992b) and the *Monticello Mill Tailings Site, Operable Unit III, Surface- and Ground-Water Remedial Investigation/Feasibility Study Field Sampling Plan* (Chem-Nuclear Geotech, Inc. 1992c) include Sampling and Analysis Plans for these media.

1.2 DATA QUALITY OBJECTIVES

Data quality objectives (DQOs) have been defined by both the American Society for Testing and Materials (ASTM) and the U. S. Environmental Protection Agency (EPA). The ASTM Standard ES 16-90 defines DQOs as "statements about the level of uncertainty that a decision maker is willing to accept in results derived from environmental data." According to the EPA (US-EPA 1987a), DQOs are "qualitative and quantitative statements that specify the quality of the data required to support the Agency's decisions during remedial response activities." The DQO development process involves the identification of decision types, data uses, data quality/quantity needs, data users, and the design of a data collection program that will satisfy the requirements of these elements (US-EPA 1987a). For environmental monitoring purposes, DQOs are primarily defined by the applicable or relevant and appropriate requirements (ARARs) specific to the environmental media being monitored. ARARs for the monitoring of meteorology, surface water, ground water, air, and direct environmental radiation are listed at the beginning of each of the EMP sections (Sections 2.0 - 6.0). [NOTE: Although the term "ARAR" is commonly associated with Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites, it is used in this document in association with both the GJPO and MMTS locations. While the MMTS is a National Priorities Listed CERCLA site, the GJPO is <u>not</u>.]

Historical documentation of monitoring data has been fairly extensive at both the GJPO and MMTS sites and has provided useful information regarding the direction of future monitoring for regulatory compliance. Current and future sampling plans for the various environmental media are established on the basis of assessments of historical monitoring data. Primary users of the collected data include decision makers from the DOE, EPA, and States of Colorado and Utah. Secondary data users include contractor personnel.

The quality of data collected for the GJPO, GJPORAP, and MMTS environmental monitoring programs is ensured by numerous quality control (QC) measures implemented during collection of the data. These measures are described in the "Sampling Plan" subsections of each of the environmental media sections. QC measures allow for the assessment of data precision, accuracy, representativeness, completeness, and comparability (see Definitions section).

1.3 FACILITY DESCRIPTIONS AND HEALTH EFFECTS

1.3.1 Grand Junction Projects Office

The GJPO is located in Mesa County, Colorado, immediately south and west of the Grand Junction city limits (Figure 1-1), in Sections 26 and 27 of Township 1 South, Range 2 West, Ute Principal Meridian. Lying within an accretionary bend of the Gunnison River, the Facility occupies an elongated, north-south-trending tract of 22.8 hectares (56.4 acres), which is bounded on the west by the river and on the north, south, and east by county, city, and private property. There are approximately 30 structures within the Facility's bounds. Most are occupied during normal working hours by the more than 700 employees of Geotech, DOE, Oak Ridge National Laboratories (ORNL), Oak Ridge Associated Universities, and the General Services Administration. Technical, administrative, and support services are provided to various DOE, U. S. Department of Defense (DOD), and EPA programs by these personnel. Analytical laboratory and construction-related services support a variety of remedial action programs, including the Grand Junction Vicinity Properties project, the Formerly Utilized Sites Remedial Action Program, the Surplus Facilities Management Program (SFMP), work associated with DOE Defense Decontamination and Decommissioning (Defense D&D) Program, and projects funded by the EPA and DOD.

Historically, programs directed primarily toward uranium procurement, domestic uranium resource evaluation, and the advancement of geologic and geophysical techniques were conducted at the site. The technology, equipment, procedures, and personnel base developed through these programs have proven invaluable to other DOE programs. Today, the GJPO maintains a personnel base and fully equipped laboratories that are uniquely suited to the support and management of environmental restoration activities.

Operations at the GJPO are conducted in an environmentally safe and responsible manner. Waste disposal operations are conducted in compliance with all applicable policies and regulations. Currently, the GJPO is a conditionally exempt small quantity generator of hazardous and mixed wastes. Facility sanitary wastewater is discharged to the local Publicly Owned Treatment Works in accordance with the conditions established in an Industrial Pretreatment Permit issued by the city of Grand Junction. Solid, nonhazardous waste is routed to the local Mesa County landfill. No waste treatment activities occur on the Facility.

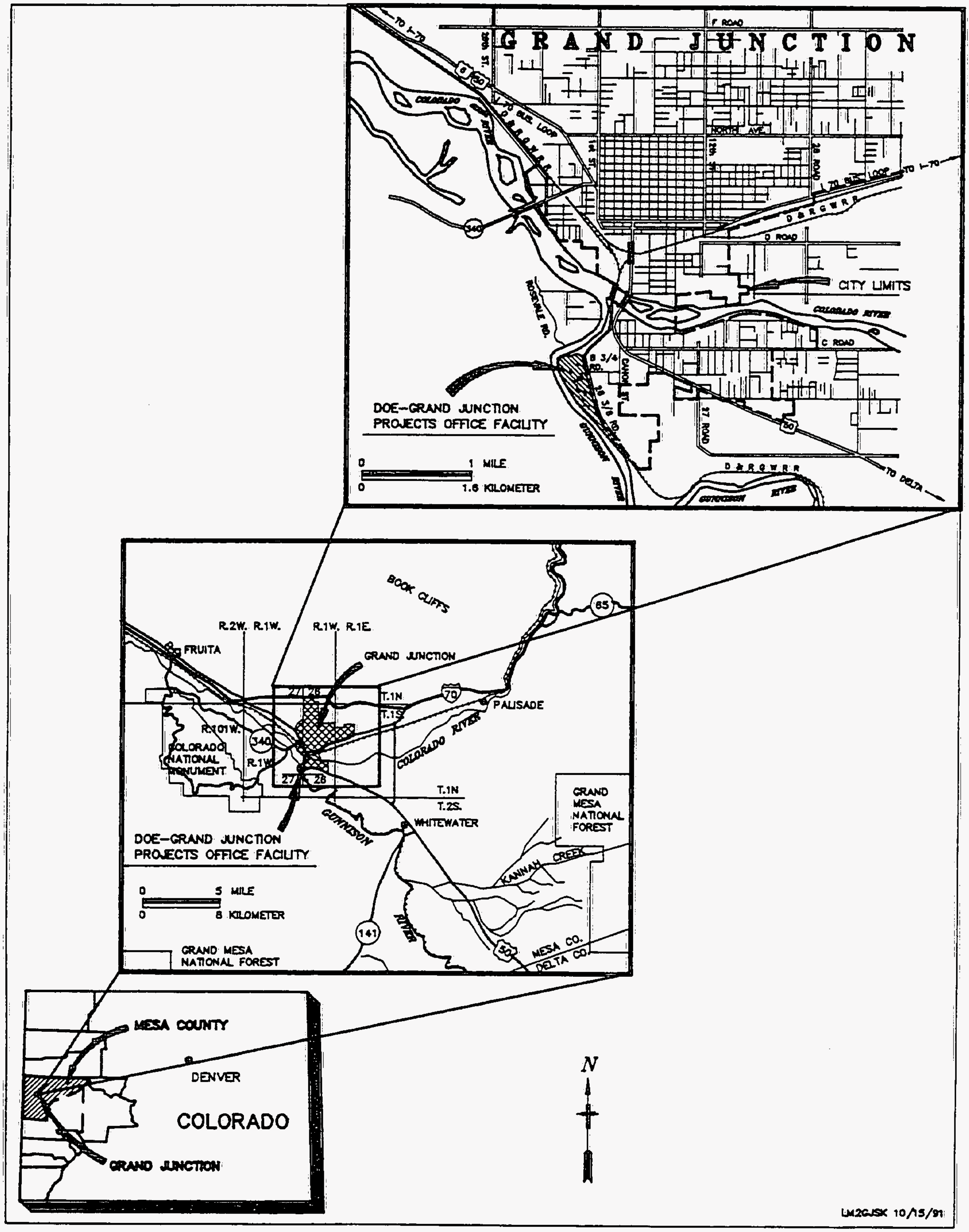

Figure 1-1. Site Location Map for the GJPO Facility

1.3.2 Grand Junction Projects Office Remedial Action Project

The GJPORAP encompasses activities associated with the removal of uranium mill tailings and mill-related contamination from early operations at the GJPO. The GJPO Facility lands were first acquired by the U. S. War Department in August 1943 for the Manhattan Engineer District. From 1943 through 1945, the U. S. Vanadium Corporation constructed and operated for the federal government a central refinery, the purpose of which was to roast and further concentrate green sludges of uranium oxide that were obtained as by-products of vanadium production from U. S. Vanadium Corporation and federal government vanadium plants in Uravan and Durango, Colorado. The resultant 20-percent uranium oxide sludge was shipped to Tonawanda, New York, for further refining to black oxide.

In December 1947, the U. S. Atomic Energy Commission established the Colorado Raw Materials Office at the site to manage the domestic uranium procurement program. The office was responsible for the receipt, sampling, and analysis of uranium and vanadium concentrates purchased from ore processing operations in the western United States. A total of 173,650 tons of uranium oxide and 14,300 tons of vanadium oxide was received and stockpiled in steel drums at the Facility from 1948 to 1971.

A pilot-plant program was initiated in 1953 with the construction of a small plant intended for research into the development of a resin-in-pulp milling process. After 1954, the pilot-plant program was dedicated to amenability testing of uranium ores and to the development and testing of new uranium milling processes. A new larger pilot plant consisting of two large mill buildings, a crushing and sampling plant, office, laboratory, warehouse, and maintenance shop was constructed in the south portion of the GJPO Facility. From 1954 until it was closed in 1958, the pilot plant operated three circuits on a 24-hour-a-day, 7-day-a-week basis. Tailings from this plant, at first, were allowed to pond just west of what is now Building 33 (Figure 1-2). A slurry line was later constructed to carry the tailings to the old gravel pit south and west of Building 7. Thenceforth, all tailings--solids and liquids--were disposed of in the gravel pit. GJPORAP activities have resulted in the removal of one of the original pilot plant buildings and excavation of the gravel pit area, which now underlies the South Pond.

All known on-site radiological contamination of ground water, ponds, and soils is believed to be the result of these past activities. The total volume of contaminated materials present on site before removal activities began in 1990 was estimated to be 132,000 cubic meters (173,000 cubic yards). The areas remediated as of October 1992 and the areas of remaining radiological contamination are shown in Figure 1-2.

Remedial action site investigations formally began for GJPORAP in 1984 when the Facility was accepted into the DOE SFMP. In 1988, the GJPO was transferred from the SFMP to the DOE Defense D&D Program. The DOE Headquarters organization was restructured in November 1990, and cleanup of the Facility is now overseen by the Northwestern Area Programs Division's D&D Branch in the Office of Environmental Restoration. Under the guidelines set forth in UMTRCA, site characterization and remedial action studies were initiated to assess the radiologic environmental hazards at

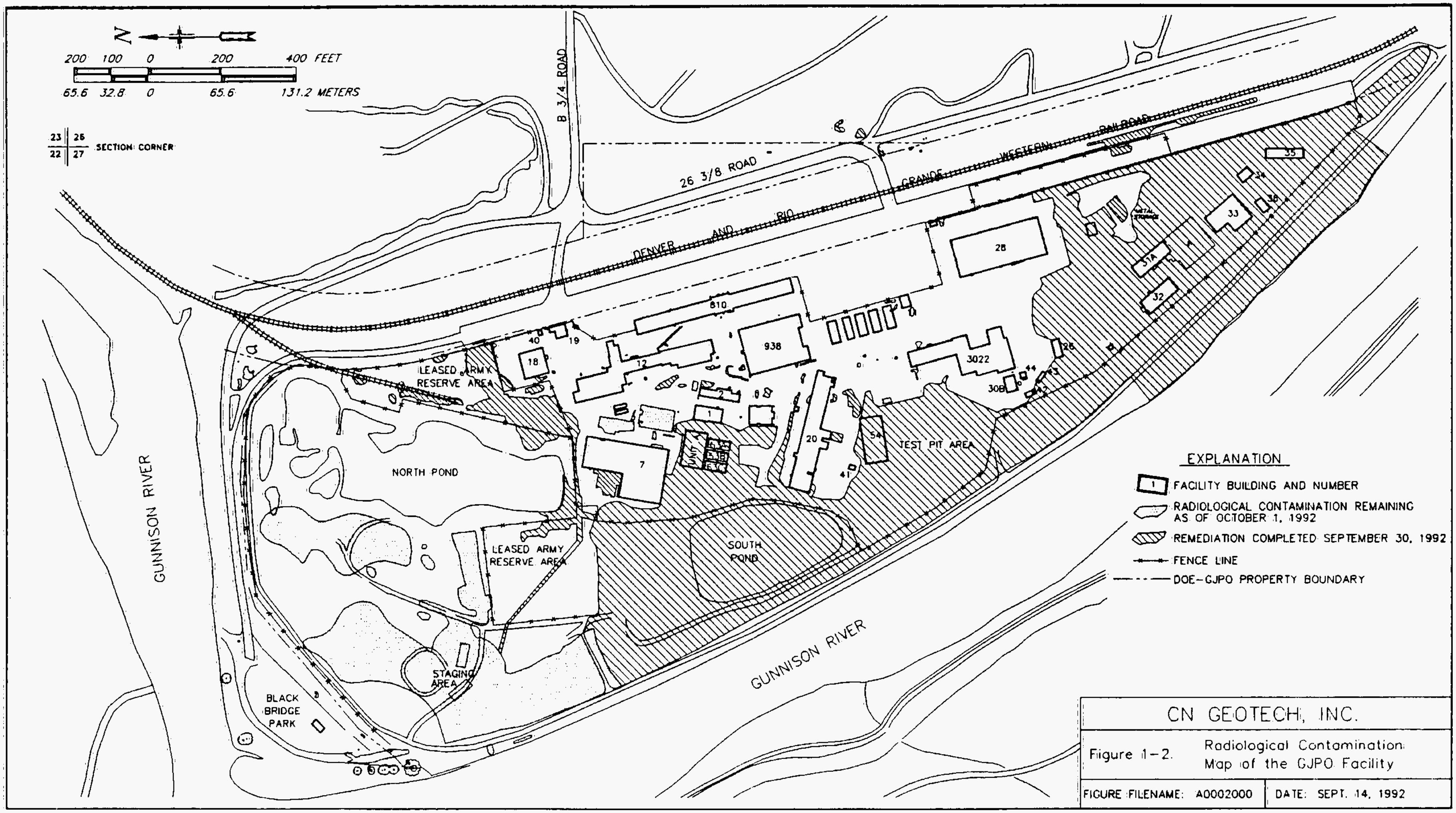

Figure 1-2. Radiological Contamination Map for the GJPO Facility

the GJPO. The initial goal was to prepare an Environmental Assessment (EA) as required by the National Environmental Policy Act (NEPA) of 1969. Federal facilities were originally exempt from the requirements of CERCLA. However, with the passage of SARA by Congress in October 1986, DOE-GJPO elected to reevaluate the Facility in accordance with CERCLA. A Remedial Investigation/Feasibility Study--Environmental Assessment (RI/FS--EA) was thus prepared to satisfy both the NEPA and SARA processes (UNC Geotech 1989a).

The GJPORAP Record of Decision (ROD) was finalized and approved by the DOE-Idaho Field Office in April of 1990 (US-DOE 1990a). On April 1,1992, functional oversight of the DOE-GJPO was transferred from the DOE-Idaho Field Office to the DOE-Albuquerque Field Office. Remedial action activities at the GJPO are currently ongoing.

1.3.3 GJPO Health Effects

The potential for adverse health effects has been quantitatively evaluated from both a radiological and nonradiological standpoint. The quantitative results are presented in the Final RI/FS--EA (UNC Geotech 1989a) and in the National Emission Standards for Hazardous Air Pollutants (NESHAPs), Subpart H Reports (Chem-Nuclear Geotech, Inc. 1990a, 1991a).

In general, radiation levels at the GJPO Facility are practically indistinguishable from background radiation levels. For example, the highest value of atmospheric radon concentration measured decreases to background levels within 61 meters (200 feet) of the Facility's boundary. Exposure to gamma radiation above background levels is confined to the actual contaminated areas located on the Facility. Airborne uranium, thorium-230, and radium-226 particulates have not been measured in concentrations above established DOE guidelines on the GJPO Facility.

Calculations have been performed by Geotech (Chem-Nuclear Geotech, Inc. 1990a, 1991a) to model the dispersion and radiological dose to the maximally exposed off-site individual and the collective population dose within 80 kilometers (km) (50 miles) of the GJPO Facility. The modeling was undertaken each year to demonstrate compliance with 40 CFR Part 61, Subpart H (NESHAPs) and DOE Order 5400.5, *Radiation Protection of the Public and the Environment*. Results of the 1990 and 1991 modeling indicated that the dose to the maximally exposed individual was below the regulatory limit of 10 millirems per year (mrem/yr) effective dose equivalent.

A number of toxic elements contained in the tailings at the GJPO Facility have leached into the shallow, alluvial ground water and surface ponds on the site. The ground water and ponded surface waters exhibit elevated concentrations of uranium, molybdenum, selenium, arsenic, and radium (see Ground Water and Surface Water Sections 3.1.2 and 4.2.2) that make them unfit for human and livestock consumptive purposes. However, the health risk to humans and livestock is considered slight because these waters are not used for any purpose, and the elevated contaminant levels drop below the

Colorado Water Quality Standards once the ground water leaves the Facility and enters the Gunnison River.

The rationale for the elements of the EMP at the GJPO was developed on the basis of the preceding discussion, and most importantly, on the fact that the levels of radioactive and nonradioactive contaminants emanating from the Facility are practically indistinguishable from the levels of natural background radiation and pose no significant risk to the local population.

1.3.4 Monticello Mill Tailings Site

The DOE-GJPO also oversees the MMTS, which encompasses the activities associated with the removal of uranium mill tailings and other mill-related contamination from the inactive Monticello Millsite and peripheral properties (MRAP) and the activities associated with remediation of surface and ground waters on and below the millsite (MSGRAP). The millsite is a 31.6-hectare (78-acre) tract of land located in San Juan County, Utah, in Section 36 of Township 33 South, Range 23 East, and Section 31 of Township 33 South, Range 24 East, Salt Lake Meridian, and is within the city limits of Monticello (Figure 1-3). Included in the millsite acreage is the former mill area, which covers approximately 4 hectares (10 acres), and the tailings impoundment area, which covers the remaining 27.6 hectares (68 acres) (Figure 1-4). None of the original mill process buildings remain, but contaminated foundations and scrap materials are buried on site. The tailings impoundment area contains approximately 1,530,000 cubic meters (2.0 million cubic yards) of tailings and contaminated soil in four discrete piles. An additional 305,800 cubic meters (400,000 cubic yards) of contaminated material is present on adjacent open lands (Marutzky and others 1985).

The MMTS also encompasses activities associated with the deposition of uranium mill tailings and associated contaminated materials at a proposed permanent repository, located on the South Site. The South Site is a 347-hectare (858.5-acre) tract of land south of the Monticello Millsite (Figure 1-3).

The Monticello mill was constructed in 1942 and was operated by various companies through 1960. Prior to 1955, the environmental problems receiving attention at the Monticello mill arose from the salt roast method used to enhance vanadium recovery. An average of nearly 1,182 kilograms (2,600 pounds) of dust containing 0.363 percent uranium oxide and 1.52 percent vanadium pentoxide escaped daily through the roaster stack (Allen and Klemenic 1954). Corrosion of wire fences, clotheslines, and galvanized roofs was verified by the mill operator in response to complaints from nearby residents.

Liquid effluent from the salt roast/carbonate leach plant, which contained higher-than-background concentrations of chloride, sulfate, carbonate, bicarbonate, sodium, and other dissolved species, was released into Montezuma Creek during early operations. Releases of radium-226 were of special concern; soluble radium activity in Montezuma Creek was found to be 160 picocuries per liter (pCi/L). Additionally, suspended solids were found

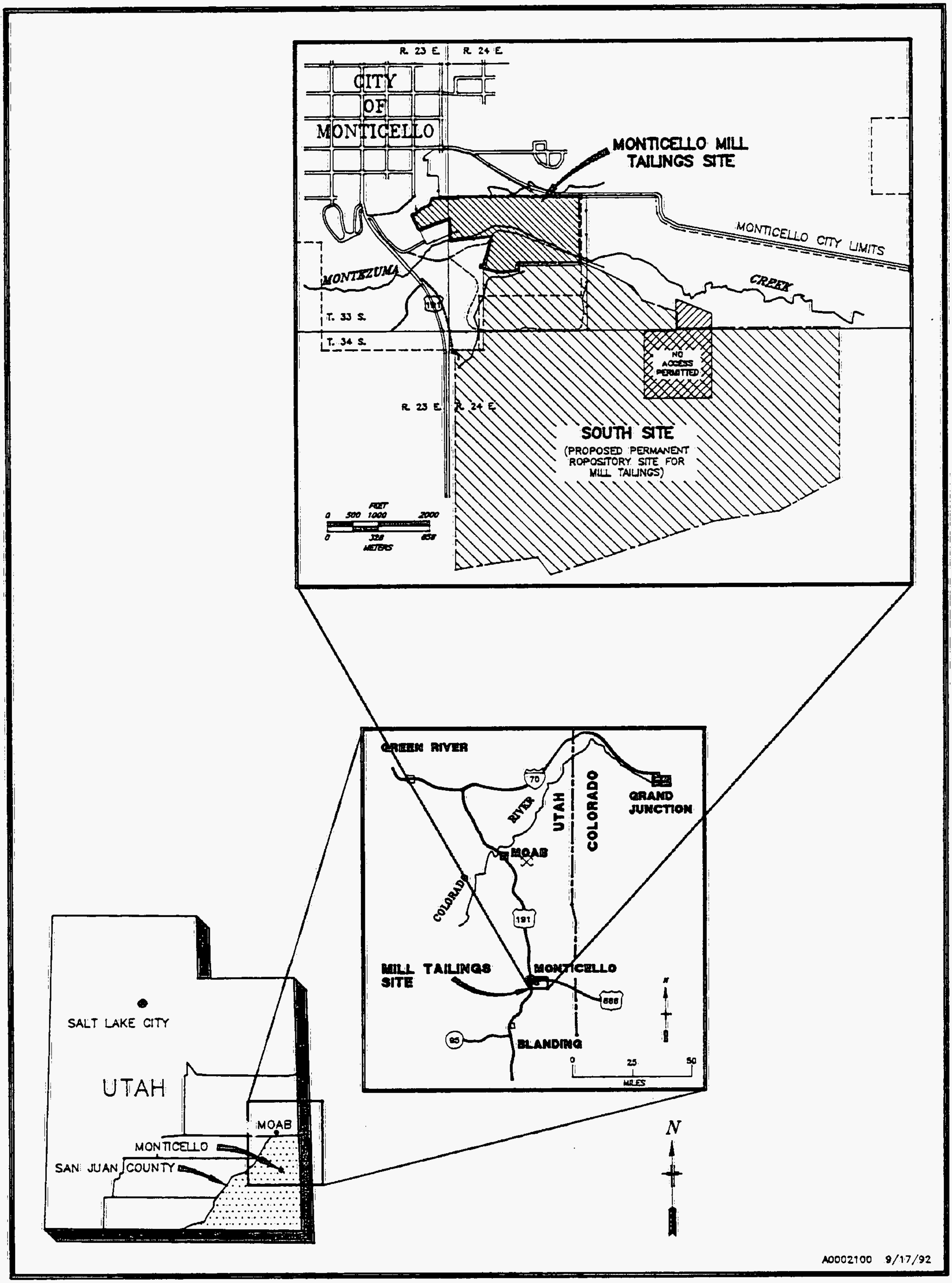

Figure 1-3. Site Location Map for the Monticello Millsite

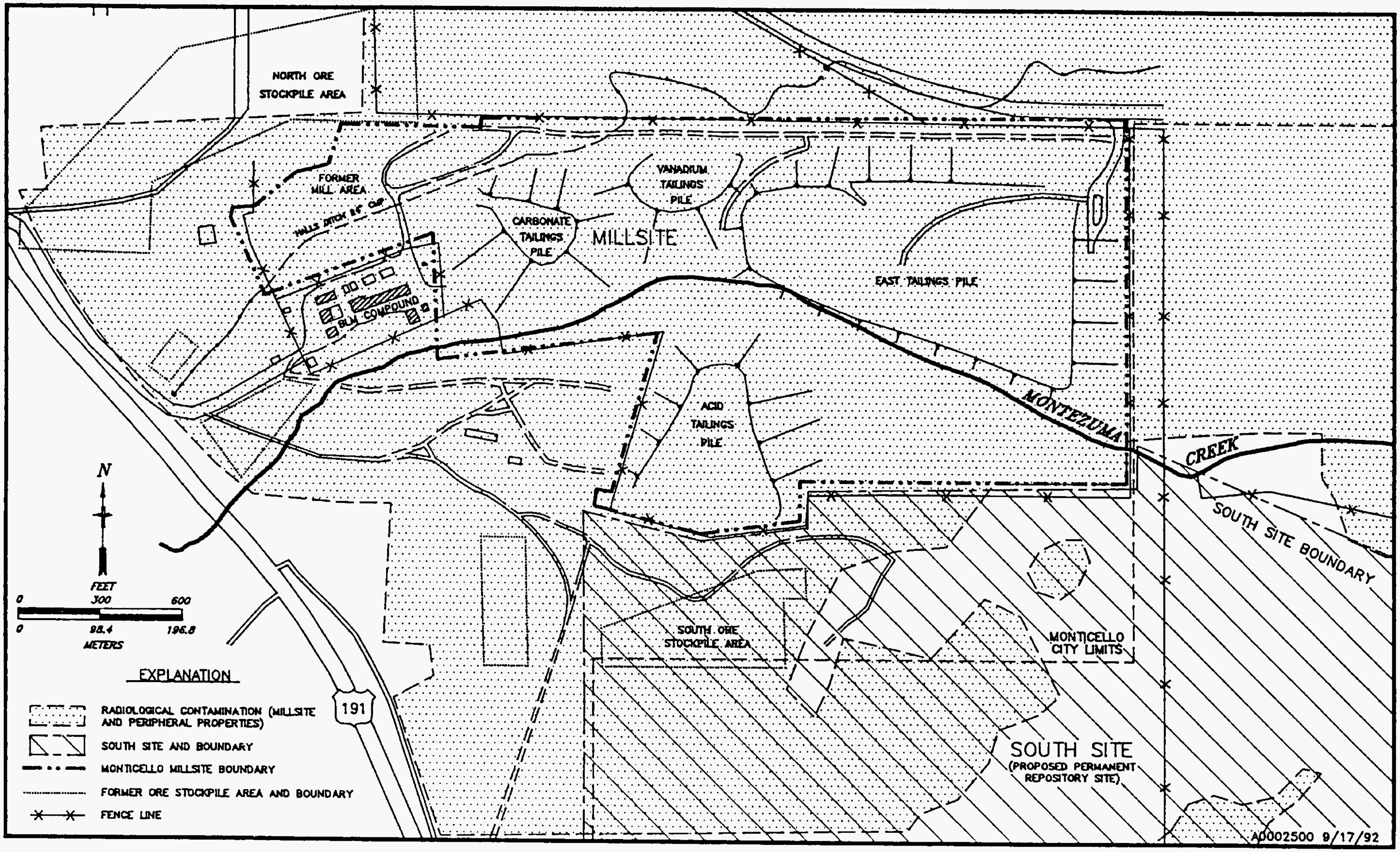

Figure 1-4. Radiological Contamination Map for the Monticello Millsite

to contain considerable radium activity, and it was discovered that dry tailings were being eroded into the creek (Whitman and Beverly 1958).

Cleanup activities conducted since the time of mill closure reduced the release of radium-226 and stabilized the tailings piles, but water contamination from leaching of the mill tailings remains a problem. Extensive hydrologic monitoring conducted at the millsite (Bendix 1980; Korte and Thul 1981, 1982, 1983, 1984; Korte and Wagner 1985, 1986; Sewell and Spencer 1987; UNC Geotech 1988a, 1989b, 1990b; Chem-Nuclear Geotech, Inc. 1991b, 1992d) has demonstrated that all four tailings piles contribute to the contamination of ground water and surface water, both on and off of the site.

Other environmental monitoring has included meteorological and atmospheric radon measurements and air particulate sampling. Radon emissions at all four tailings piles historically exceeded EPA standards, whereas air particulate concentrations were below regulatory limits.

Responsibility for the administration, maintenance, and environmental monitoring of the MMTS (formerly operated by the Atomic Energy Commission) resides with DOE-GJPO and DOE Headquarters. The site was accepted into the SFMP in 1980, and in November 1989, was transferred to the DOE Office of Environmental Restoration and Waste Management, Eastern Area Programs Division, D&D Branch. In May 1991, program oversight responsibility for the Monticello projects was transferred to the Northwestern Area Programs Division, D&D Branch. MRAP and MSGRAP were formulated to minimize potential health hazards to the public that are associated with the millsite tailings and to clean up contaminated surface and ground water on and below the millsite. To provide a basis for making decisions regarding the remediation of the site, an environmental and engineering characterization was completed and documented in the *Monticello Mill Tailings Site Site Analysis Report* (Abramiuk and others 1984).

With the passage of SARA, the activities at the Monticello Millsite also came under the regulatory framework of CERCLA. During 1987, existing environmental site characterization and engineering documents were revised into the format of a CERCLA RI/FS. The DOE, EPA, and the State of Utah entered into a Federal Facility Agreement (FFA), pursuant to CERCLA Section 120, in December 1988. This agreement stipulated the procedural framework for developing and implementing response actions under CERCLA. On November 16, 1989, the Monticello Millsite was listed on the National Priorities List. The RI/FS was modified in 1989 to include the requirements for an EA under NEPA and was finalized in March 1990 as the *Final Remedial Investigation/Feasibility Study--Environmental Assessment for the Monticello, Utah, Uranium Mill Tailings Site* (UNC Geotech 1990c).

The MMTS ROD, which describes remedial actions for MRAP, was signed September 20, 1990 (US-DOE 1990b). Remedial action started on August 19, 1991 with the abandonment of the older Atomic Energy Commission wells. After tailings removal is completed and several years of surface and ground water monitoring data are analyzed, preparations for the MSGRAP ROD will begin.

The permanent repository that will be constructed to contain tailings removed from the millsite and the Monticello area will be located on the South Site, which is shown in Figure 1-3. Before repository construction begins at the South Site, baseline environmental monitoring will be conducted. Environmental monitoring work plans will be developed and submitted to the appropriate regulatory agencies according to a schedule that allows sufficient time for both regulatory review and collection of a minimum of four quarters of data. The repository will be designed to control contamination of ground water beneath the stabilized tailings to the extent necessary to comply with applicable regulations. After construction is completed, the Long Term Maintenance and Surveillance Program will assess compliance with ground water protection standards. Surface water, air quality, and meteorological data will be collected as required to assess emissions before and during repository construction and closure. At present, there is a meteorological data base that includes 9 years of historical data at the nearby millsite.

1.3.5 Monticello Millsite Health Effects

A quantitative assessment of the potential health effects associated with tailings-related contamination is presented in the Final RI/FS--EA (UNC Geotech 1990c). The assessment is based on site-specific data collected from 1981 through 1986. Additional data of a more limited scope were collected during 1988, 1989, and 1990 and indicate that the ground water and atmospheric radon concentrations are consistent with previous years' values. In view of this, and because there were no operational activities at the site during this period that would be expected to cause a significant increase in the source terms, a risk assessment based on the 1988-1990 monitoring data was not undertaken. The following risk estimates, summarized from the Final RI/FS--EA (UNC Geotech 1990c), are considered to be representative of the site.

Population doses to Monticello residents from natural background radiation and from the tailings piles in their present condition are presented in Table 1-1. The doses are based on a population of 2,469.

A potential for adverse health effects from chance exposure to nonradiological contaminants found in the waters of Montezuma Creek, associated floodplain soils, and uranium tailings piles exists, although contaminant levels are low. Toxicity potentials were derived from a comparison of contaminant levels with acceptable intakes for chronic exposure (AICs). Tables showing the comparison are in the Final RI/FS--EA (UNC Geotech 1990c). When average concentrations in the tailings were used, none of the dose levels were exceeded. When maximum concentrations in the tailings were used, copper, uranium, and zinc exceeded the recommended exposure limits for children. However, because of the low population densities along the Montezuma Creek drainage and the land-use patterns in the area, it is unlikely that individuals would receive chronic exposures to these maximum concentrations.

Table 1-1. Population Dose Commitments to Monticello Residents from Natural Background and Present Enhanced Conditions

Source	Dose Commitment (person-rem per year) Whole Body	Lung
Natural Background		
Direct External Exposure	316	NA[a]
Radon Daughers	NA	1,265
Enhanced Conditions		
Direct External Exposure	165	NA
Radon Daughters	NA	188

[a]NA = not applicable.

Some elements found in the surface waters of Montezuma Creek, including selenium, zinc, manganese, arsenic, and molybdenum, regularly exceed State of Utah water quality standards. The potential for exposure to these elements dictates that this water should not be used for human or livestock consumptive purposes. Use of this water to irrigate the alfalfa on which cattle graze appears to be acceptable, because average exposure doses do not exceed AICs.

Although the potential for adverse health effects from conditions at the Monticello Millsite is low, the health effects issue is the basis and focus of the EMP.

2.0 Meteorology

2.0 METEOROLOGY

2.1 REGULATORY REQUIREMENTS

Meteorological monitoring for the GJPO, GJPORAP, and MMTS is conducted to comply with all ARARs outlined in Table 2-1.

2.2 GJPO/GJPORAP

Meteorological monitoring for the GJPO/GJPORAP involves collection of on-site and, at times, off-site meteorological monitoring data. An on-site meteorological monitoring station provides site-specific data that are used to compile baseline meteorological data. Off-site meteorological data are available from the National Weather Service station, located approximately 8 km (5 miles) northeast of the GJPO Facility at Walker Field Airport.

2.2.1 Historical Meteorological Monitoring

The first on-site meteorological monitoring station was installed in 1982 and was located approximately 55 meters (180 feet) south of the west end of Building 20 on a 3-meter (10-foot) tower (Figure 2-1). The station was equipped with Campbell Scientific, Phys-Chem Research, and YSI instrumentation, and measured wind speed, wind direction, relative humidity, temperature, and barometric pressure.

In the fall of 1992, a new station was erected on a 10-meter (33-foot) tower on the north end of the Facility (Figure 2-1). Existing temperature, relative humidity, and wind sensors were replaced with new sensors that met DOE and EPA accuracy and threshold specifications. As recommended by DOE's *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (US-DOE 1991), wind speed and wind direction sensors were mounted at a 10-meter height to characterize winds at potential release heights.

The telemetry capabilities of the station allow instant access to the data being collected. Measurements are taken every 15 seconds and are averaged at 1-hour intervals by the data logger and associated software. Specifications for the station's instrumentation, including the instrument type, manufacturer, accuracy, range, and threshold value, are listed in Table 2-2.

Data from a National Weather Service station (see Figure 2-2 for location) were used in 1990 and 1991 to perform dose modeling studies for air emission compliance. This off-site station includes instrumentation for measuring wind speed, wind direction, temperature, winds aloft, precipitation, ceiling, cloud cover, and solar radiation.

Table 2-1. ARARs for Meteorological Monitoring

Standard, Requirement, Criterion, or Limitation	Citation	Description
ARARs Common to the GJPO, GJPORAP, and MMTS		
General Environmental Protection Program	DOE 5400.1 Chapter IV Part 6	Representative meteorological data are required at DOE facilities to support environmental monitoring requirements. Meteorological information must be available at or in the vicinity of DOE facilities to characterize atmospheric transport and diffusion conditions, characterize conditions important to environmental surveillance activities, and confirm compliance with and implementation of regulations and DOE Orders.
Radiation Protection of the Public and Environment Compliance demonstrated	DOE 5400.5 Chapter I	Demonstrations of compliance with this order generally will be based on calculations that make Part 8a use of information obtained from environmental Chapter II monitoring and surveillance programs. Part 6b(1) with the dose limits of this Order is by the use of a dose model. The dose model requires the input of meteorological data that characterize the atmospheric transport and diffusion conditions in the vicinity of the site.
Radiological Effluent Monitoring and Environmental Surveillance	DOE Environmental Regulatory Guide Chapter 4.0	Each DOE facility must establish a meteorological monitoring program that is appropriate to the activities at the site. Meteorological considerations, which characterize atmospheric dispersion conditions, are an integral part of the dose assessment capabilities both planned and unplanned releases. DOE sites are required to have on-site measurement capabilities of wind direction, wind speed, and atmos-

Table 2-1 (continued). ARARs for Meteorological Monitoring

Standard, Requirement, Criterion, or Limitation	Citation	Description
Radiological Effluent Monitoring and Environmental Surveillance (continued)	DOE Environmental Regulatory Guide Chapter 4.0	pheric stability available to evaluate atmospheric dispersion in the vicinity of facilities and to perform the required dose calculations specified in this document and 40 CFR Part 61. However, some sites may choose to establish a meteorological program that makes use of meteorlogical measurements from off-site sources.
Radiological Effluent Monitoring and Environmental Surveillance (continued)	DOE Environmental Regulatory Guide Chapter 4.0	If data from an off-site source are used, they must be representative of conditions at the DOE facility statistically valid, and consistent with on-site monitoring data requirements. Specific meteorlogical information requirements for each facility must be based on the magnitude of potential source terms, nature of potential releases from the facility, possible pathways to the atmosphere, distances from release points to critical receptors, and proximity of other DOE facilities. Meteorological information requirements for facilities must also be sufficient to support environmental monitoring and surveillance programs.
<u>ARAR Specific to the GJPO/GJPORAP</u>		
Clean Air Act	40 CFR 61 Subpart H (NESHAPS)	Meteorological information is required for input into a dose model used to calculate the highest effective dose equivalent to any member of the public.

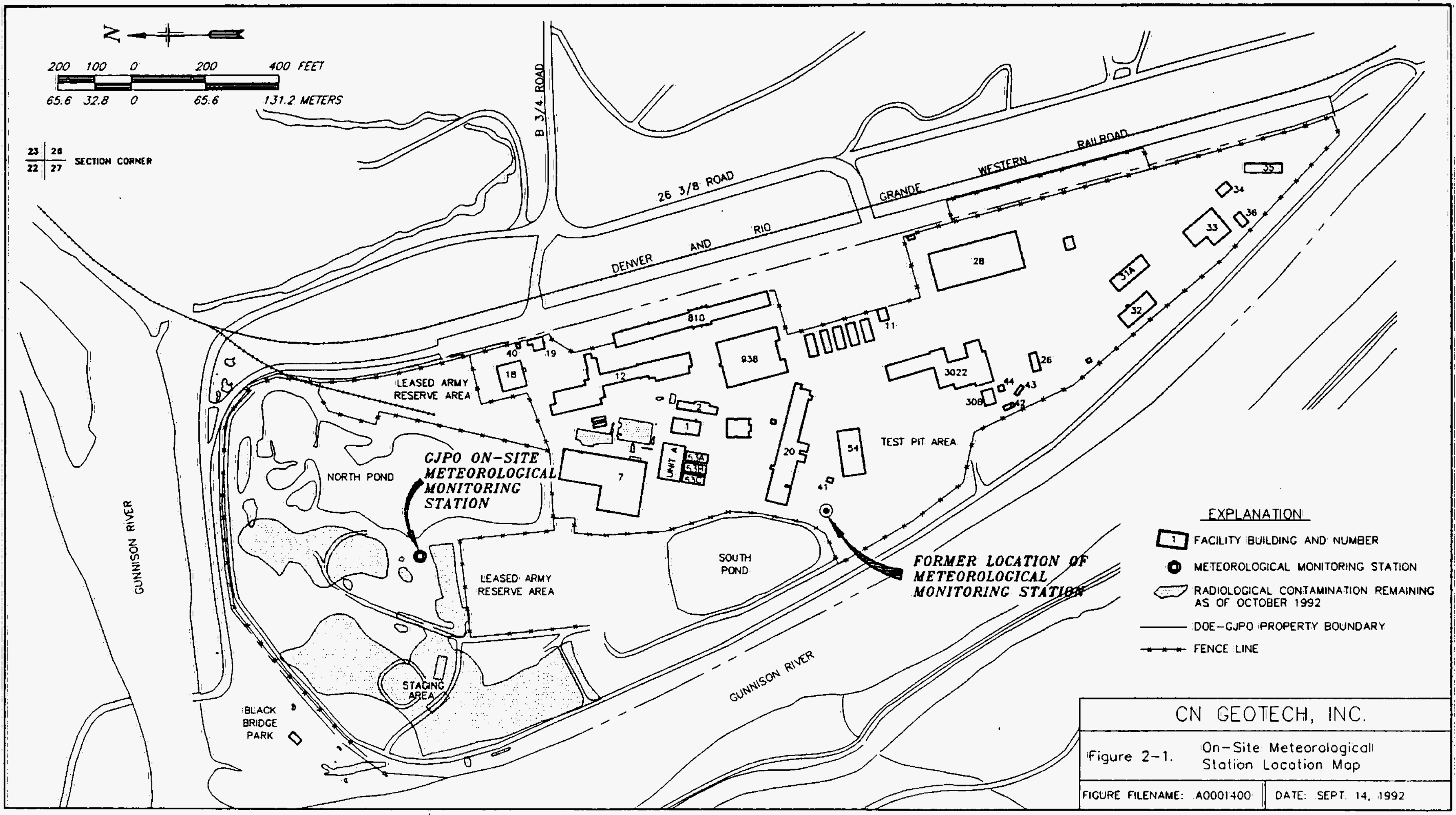

Figure 2-1. On-Site Meteorological Station Location Map for the GJPO Facility

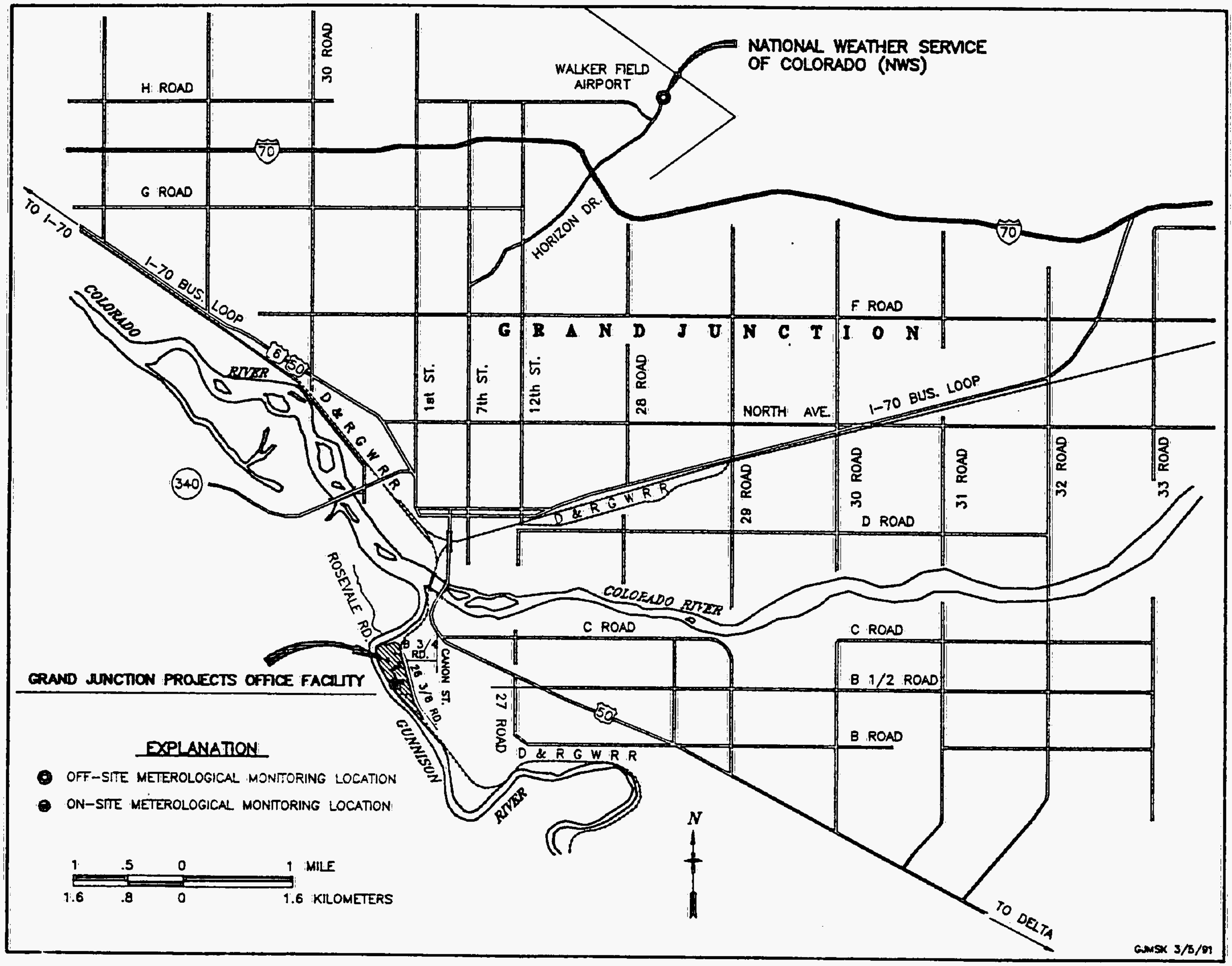

Figure 2-2. Off-Site Meteorological Station Location Map for the GJPO Facility

Table 2-2. On-Site Meteorological Equipment Specifications, GJPO/GJPORAP

Instrument Type	Manufacturer	Accuracy	Range	Threshold
Wind Speed	Nova Lynx	± 0.5%	0-90 mph	0.9 mph
Wind Direction	Nova Lynx	± 0.5%	0-360°	1.0 mph
Relative Humidity	Nova Lynx	± 2%	0-100%	NA[a]
Barometric Press.	Nova Lynx	± 1 mb	600-1045 mb	NA
Temperature	Nova Lynx	± 0.4°C	-40 to +60°C	NA
Solar Radiation	Nova Lynx	± 5%	0.35-1.15 μm	NA

[a]NA = not applicable.

2.2.2 Planned Meteorological Monitoring

2.2.2.1 Monitoring Objectives

The objectives of the meteorological monitoring program for the GJPO/GJPORAP are

1. to establish a meteorological data base upon which decisions can be made concerning environmental monitoring activities; and

2. to provide data to characterize atmospheric transport and diffusion conditions in the vicinity of the GJPO Facility for assessments of the impacts of airborne releases on public health and safety.

Historical meteorological monitoring has accomplished the first objective; current and future monitoring will accomplish the second objective.

DOE Order 5400.5 and 40 CFR Part 61, Subpart H, both require that meteorological data be input into an EPA-approved computer model to determine the potential impacts to members of the public from DOE activities. To comply with these requirements, data from the on-site meteorological monitoring station and possibly from the off-site station will be used in the MICROAIRDOS model.

2.2.2.2 Sampling Plan

Meteorological data will continue to be collected at the GJPO with the Nova Lynx station at a measurement frequency of 15 seconds and a data averaging frequency of 1 hour. Data will be downloaded every Monday, Wednesday, and Friday from the data logger to an ORACLE data base. At that time, data will be evaluated for completeness and quality.

Geotech Environmental Services personnel will field check instrumentation once a month. Field checks will involve a visual inspection to ensure that all sensors are clean and in operating order. Additionally, field calibration of the sensors will be performed, and calibration documentation will be recorded in a site log book annually. The equipment used for calibration of the meteorology sensors will be calibrated by Geotech's Electronics Laboratory personnel in accordance with their QA-approved procedures.

Procedures for operating, maintaining, and calibrating the GJPO meteorological station are described in detail in the *Sampling and Analysis Plan for Environmental Monitoring* (Chem-Nuclear Geotech, Inc. 1992a).

2.2.2.3 Data Management

The Data Manager, who is appointed by the Geotech Project Manager, will maintain a data base for all meteorological monitoring data. Data management will include downloading meteorological data into an ORACLE data base and formatting the data for report preparation and computer model input. Data will be stored in the ORACLE data base on a MicroVAX computer system and will be backed up weekly. In addition, all records, reports, and data will be stored in a permanent project file in Geotech's Records Management Section.

2.2.2.4 Data Analysis/Reporting Format

Data will be analyzed to determine if the monitoring objectives have been met. Only data of known quality will be used for determining whether DQOs have been met. Meteorological monitoring data will be input into an EPA-approved computer model (MICROAIRDOS) to demonstrate compliance with DOE Order 5400.5 and 40 CFR Part 61, Subpart H (NESHAPS). In addition, a summary of meteorological monitoring data will be presented in the Annual Site Environmental Report.

2.2.3 Responsible Organizations

Meteorological monitoring for the GJPO/GJPORAP is the responsibility of the DOE-GJPO Manager. The Geotech Program Manager directs the Geotech Project Manager to complete the necessary requirements of the program. Responsibility for implementing monitoring currently resides with the Environmental Services Section of Geotech.

2.3 MMTS

2.3.1 Historical Meteorological Monitoring

An on-site meteorological monitoring station was installed on the Monticello Millsite property in 1982 to collect site-specific data. The station, which was mounted on a 3-meter (10-foot) tower on the Acid Tailings Pile (Figure 2-3), was equipped with a Campbell Scientific CR21 micrologger to collect real-time meteorological data on an hourly basis. Information generated by the station included wind speed, wind direction, relative humidity, temperature, and barometric pressure. Data from this station were used in 1988 to model atmospheric dispersion of radon generated at the Monticello tailings site.

In the fall of 1991, the station was replaced with upgraded instrumentation and relocated to the South Site (Figure 2-3). Existing temperature, relative humidity, barometric pressure, and wind sensors were replaced with new sensors that met DOE and EPA accuracy and threshold specifications. Wind speed and wind direction sensors were mounted at a 10-meter (33-foot) height, as recommended by DOE's *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (US-DOE 1991) to characterize winds at potential release heights. For characterization of atmospheric stability and precipitation, a solar radiation sensor and weighing-bucket-type gauge were added, respectively.

The telemetry capabilities of the station allow instant access to the data being collected. Measurements are taken every 15 seconds and are averaged at 1-hour intervals by the data logger and associated software. Specifications for the station's instrumentation, including the instrument type, manufacturer, accuracy, range, and threshold value, are in Table 2-3.

Table 2-3. On-Site Meteorological Equipment Specifications, MMTS

Instrument Type	Manufacturer	Accuracy	Range	Threshold
Wind Speed	Nova Lynx	± 0.5%	0-70 mph	0.5 mph
Wind Direction	Nova Lynx	± 0.5%	0-360°	0.9 mph
Relative Humidity	Nova Lynx	± 2%	0-100%	NA[a]
Barometric Press.	Nova Lynx	± 1 mb	600-1045 mb	NA
Temperature	Nova Lynx	± 0.4°C	-40 to +60°C	NA
Solar Radiation	Nova Lynx	± 5%	0.35-1.15 μm	NA
Precipitation	Nova Lynx	± 3%	Unlimited	0.01"

[a]NA = not applicable.

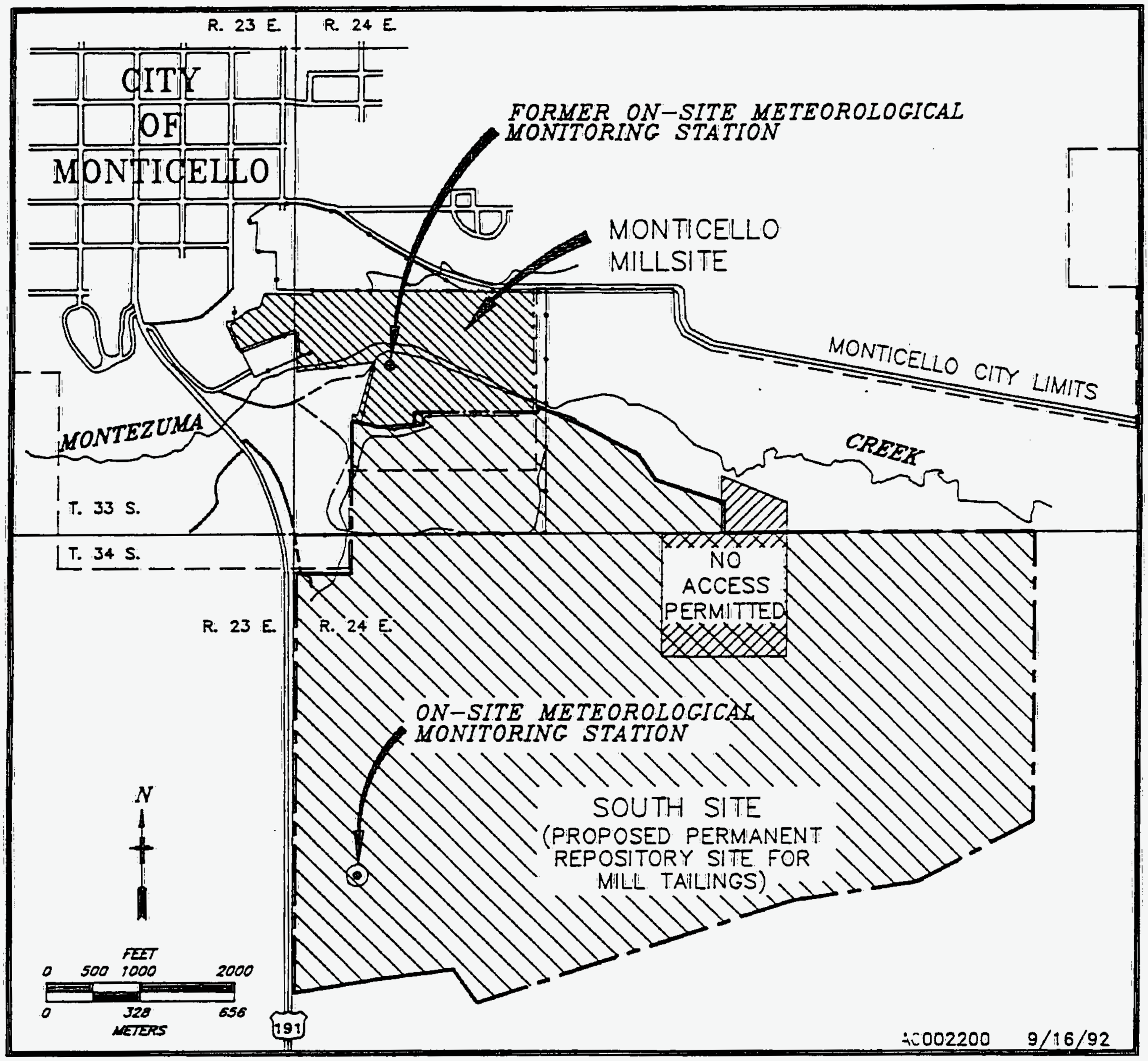

Figure 2-3. On-Site Meteorological Station Location Map for the Monticello Millsite

2.3.2 Planned Meteorological Monitoring

2.3.2.1 Monitoring Objectives

The objectives of the meteorological monitoring program for the MMTS are

1. to establish a meteorological data base upon which decisions can be made concerning environmental monitoring activities; and

2. to provide data to characterize atmospheric transport and diffusion conditions in the vicinity of the Monticello Millsite for assessments of the impacts of airborne releases on public health and safety.

Historical monitoring has accomplished the first objective; current and future monitoring will accomplish the second objective.

DOE Order 5400.5 requires that meteorological data be input into an EPA-approved computer model to determine the potential dose to members of the public from DOE activities. To comply with these requirements, on-site meteorological data will be used for input values in atmospheric transport and dosimetry models.

2.3.2.2 Sampling Plan

Sampling of meteorological data at Monticello will be the same as that described for the GJPO/GJPORAP in Section 2.2.2.2.

2.3.2.3 Data Management

Data management will be the same as that described for the GJPO/GJPORAP in Section 2.2.2.3.

2.3.2.4 Data Analysis/Reporting Format

The data analysis/reporting format will be the same as that described for the GJPO/GJPORAP in Section 2.2.2.4.

2.3.3 Responsible Organizations

Responsible organizations will be the same as those described for the GJPO/GJPORAP (Section 2.2.3).

3.0 Surface Water

3.0 SURFACE WATER

3.1 EFFLUENT MONITORING

3.1.1 Regulatory Requirements

ARARs for the radiological and nonradiological liquid effluent monitoring that are the responsibility of the GJPO are outlined in Table 3-1.

No liquid effluent is associated with the MMTS at this time.

3.1.2 GJPO/GJPORAP

Two types of liquid effluent are generated on the GJPO Facility--waste effluent discharged into an underground sewer system, which is routed to the city of Grand Junction's publicly owned treatment works, and storm water runoff, which is collected in a series of drain pipes and discharged into the South Pond (located on the Facility). The sewer effluent consists of domestic sewage and typical industrial-type discharges from the Analytical Chemistry Laboratory, Photography Laboratory, cafeteria, boiler plant, and wash bay of the maintenance shop. Storm water effluent consists of runoff from the Facility parking lots, office buildings, and paved areas. According to federal regulations outlined in 40 CFR 122, National Pollutant Discharge Elimination System (NPDES) permits are not required for either type of discharge.

3.1.2.1 Historical Liquid Effluent Monitoring

In the early days of operation, all sanitary waste waters were passed through septic tanks and then discharged into the South Pond on the GJPO Facility. The Facility was connected to the city of Grand Junction sewer system in 1981, eliminating the need for septic systems. During 1987, the GJPO applied for an Industrial Pretreatment Permit, at which time an effluent profile was developed to characterize the discharge. The effluent included approximately 23 kilograms (50 pounds) per year of laboratory acids--mainly nitric and hydrochloric--in dilute concentrations. Less than 1 gram per year of organics such as aldrin, lindane, endrin, and toxaphene was present. Several inorganics also were discharged to the sewer system in low concentrations. During the permit application period, several pretreatment measures, such as reclaiming silver in the Photography Laboratory and installing grease traps in the cafeteria and maintenance shop, were implemented.

An Industrial Pretreatment Permit (No. 0023) was issued to the GJPO by the city of Grand Junction/Mesa County in March 1989. The issuance of the permit was in accordance with provisions of the Federal Water Pollution Control Act, as amended by the Clean Water Act of 1977, and with Article 10 of Chapter 25, Code of Ordinance for the city of Grand Junction. The permit requires the GJPO to sample the sewer effluent

Table 3-1. ARARs for Liquid Effluent Monitoring

Standard, Requirement, Criterion, or Limitation	Citation	Description
ARARs Common to the GJPO and GJPORAP		
General Environmental Protection Program	DOE 5400.1 Chapter II Part 5	A Radioactive Effluent and On-Site Discharge Data Report is required annually and must include unplanned releases of radioactive materials in effluents.
	DOE 5400.1 Chapter IV Part 5a	1. Effluent monitoring shall be conducted at all DOE sites to satisfy the following program objectives: a. Evaluate the effectiveness of effluent treatment and control. b. Identify potential environmental problems and evaluate the need for remedial actions or mitigation measures. c. Support permit revision and/or reissuance. d. Detect, characterize, and report unplanned releases.
Radiation Protection of the Public and the Environment	DOE 5400.5 Chapter I Part 3, Part 7 Chapter II Part 3d	1. The Best Available Technology (BAT) selection process through a BAT Analysis Implementation Plan shall be implemented if radionuclides greater than 5 times the Derived Concentration Guide (DCG) are found. 2. The exposure of members of the public to radiation sources as a consequence of all routine DOE activities shall not cause an annual effective dose equivalent of greater than 100 mrem.

Table 3-1 (continued). ARARs for Liquid Effluent Monitoring

Standard, Requirement, Criterion, or Limitation	Citation	Description
Radiological Effluent Monitoring and Environmental Surveillance	DOE Environmental Regulatory Guide Chapter 2	1. Evaluation of effluent streams--all effluent streams from DOE facilities shall be evaluated and their potential for release of radionuclides assessed. This evaluation is required to adequately control such releases. The results of these assessments provide the basis for the facilities' Effluent Monitoring Program that shall be documented in the Environmental Monitoring Plan to show: a. Effluent monitoring extraction locations used for providing quantitative effluent release data for each outfall b. Procedures and equipment used to perform the extraction and measurement c. Minimum detection level and accuracy d. Frequency and analyses required for each extraction location e. QA components f. Effluent outfall alarm settings 2. Liquid effluents that have the potential for radioactive contamination shall be monitored in accordance with the requirements of DOE 5400.1 and 5400.5. As appropriate, component systems may be grouped and standard procedures referenced.

Table 3-1 (continued). ARARs for Liquid Effluent Monitoring

Standard, Requirement, Criterion, or Limitation	Citation	Description
Radiological Effluent Monitoring and Environmental Surveillance	DOE Environmental Regulatory Guide Chapter 2	3. Facility operators shall provide monitoring of liquid waste streams adequate to a. quantify radionuclides released from each discharge point b. alert affected process supervisors of upsets in process and emission controls 4. Continuous radionuclide monitoring should be provided on those release points that could: a. exceed 1 DCG equivalent at the point of release averaged over 1 year and that are detectable with state-of-the-art continuous monitoring devices, or b. result in unanticipated releases to the environment that could exceed 1 DCG averaged over 1 year.
National Pretreatment Standards (40 CFR Part 403)	Federal Water Pollution Control Act, as amended by Clean Water Act of 1977 (Public Law 95-217)	The standards specify quantities or concentrations of pollutants or pollutant properties that may be discharged to a POTW and specify prohibited discharges.
National Pollution Discharge Elimination System Permit Application Regulations for Storm Water Discharges	40 CFR Parts 122, 123, and 124 (*Federal Register* November 16, 1990)	This rule implements section 402(p) of the Clean Water Act, which requires EPA to establish regulations setting forth National Pollutant Discharge Elimination System permit application requirements for storm water discharges associated with industrial activity.

Table 3-1 (continued). ARARs for Liquid Effluent Monitoring

Standard, Requirement, Criterion, or Limitation	Citation	Description
Guidelines Establishing Test Procedures for the Analysis of Pollutants	40 CFR Part 136	This rule lists the analytical procedures that are approved for the testing of storm water discharge.
<u>ARARs Specific to the GJPO</u>		
Radiation Control	Colorado Department of Health Rules and Regulations Section 4.18 Part IV	The discharge limitations for releases into the sanitary sewer system is 400 pCi/L. This limit is based on the conservative assumption that neither the identity nor the concentration of any radionuclide is known.
City of Grand Junction/ Mesa County Industrial Pretreatment Permit	Article 10 Chapter 25 Code of Ordinance of the City of Grand Junction	Industrial discharge into the sanitary sewer and subsequently to the city of Grand Junction's Publicly Owned Treatment Works requires an Industrial Pretreatment Permit to comply with the provisions of the Clean Water Act of 1977. The Industrail Pretreatment Permit specifies a list of analytes with concentration limits. Semiannual monitoring and reporting is required to comply with the Industrial Pretreatment Permit.
<u>ARAR specific to the MMTS</u>		
Utah Pollution Discharge Elimination System	Title 26, Chapter 11, Utah Code Annotated, (R448-8, U.A.C)	The Bureau of Water Pollution Control has promulgated standards for surface discharges of water, which are compatible with the Federal regulation adopted pursuant to the Clean Water Act. Although currently there are no point source discharges from the Monticello Millsite, they are anticipated to occur during future remedial activities.

semiannually and to submit semiannual reports of the analyses to the city by January 31 and July 31. Table 3-2 lists the analytes required to be sampled and respective threshold limits established by the permit. Samples for oil and grease, cyanide, phenols, and pH analyses are required to be obtained by grab sampling; all other analytes are required to be obtained by flow-proportional sampling over an approximate 24-hour period. Sampling occurs from a location marked as manhole #12, shown in Figure 3-1.

Table 3-2. Discharge Limitations Established by the Industrial Pretreatment Permit Issued by the City of Grand Junction

Pollutant	Threshold Limit	Type of Sample
Biological Oxygen Demand	200 mg/L	Composite (flow-proportional)
Total Suspended Solids	250 mg/L	Composite (flow-proportional)
Oil and Grease	50 mg/L	Grab (one sample)
Chromium/Total	5.00 mg/L	Composite (flow-proportional)
Copper/Total	5.00 mg/L	Composite (flow-proportional)
Mercury/Total	0.080 mg/L	Composite (flow-proportional)
Nickel/Total	3.98 mg/L	Composite (flow-proportional)
Lead/Total	0.69 mg/L	Composite (flow-proportional)
Zinc/Total	5.00 mg/L	Composite (flow-proportional)
Cyanide	1.20 mg/L	Grab (one sample)
Phenols	10.00 mg/L	Grab (one sample)
PCBs	0.002 mg/L	Composite (flow-proportional)
Silver	0.43 mg/L	Composite (flow-proportional)
pH	5.5-9.5 units	Grab (one sample)

In addition to the permit requirements, other analyses have been performed on the sewer effluent on a voluntary basis by the GJPO to aid in the development of a pollution control data base. Since February 1989, sewer effluent has been sampled monthly for gross alpha, gross beta, total dissolved solids, chemical oxygen demand, total organic halides, and total organic carbon, in addition to the analytes listed in Table 3-2.

The storm water drain system was installed at the GJPO during the 1950s and renovated during 1992 GJPORAP remedial activities. To date, no sampling of storm water runoff has been performed. Storm water runoff from administrative office buildings and employee parking lots presently is collected and discharged into the South Pond. Because this type of runoff does not meet the regulatory definition of "being associated with industrial activity," the GJPO Facility is exempt from the requirements of the NPDES Storm Water Program.

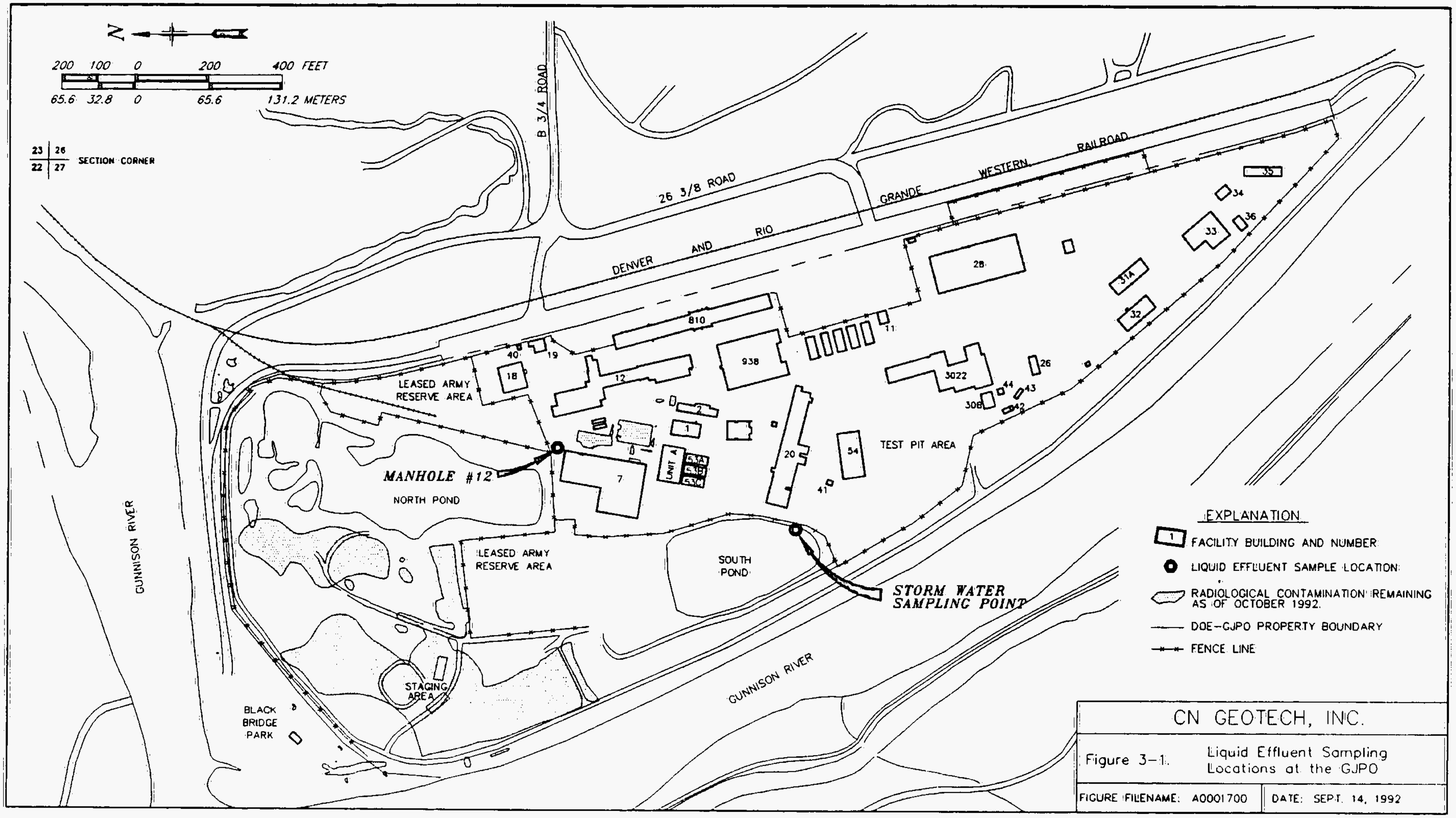

Figure 3-1. Liquid Effluent Sampling Locations at the GJPO Facility

3.1.2.2 Planned Liquid Effluent Monitoring

3.1.2.2.1 *Monitoring Objectives*

The objectives of the liquid effluent monitoring program at the GJPO Facility are

1. to verify compliance with the Industrial Pretreatment Permit issued by the city of Grand Junction.

2. to develop a baseline of typical sanitary sewer effluent concentrations for selected constituents against which future measurements can be compared.

3. to characterize the quality of storm water runoff discharged from the storm water collection system.

Sampling of the sewer effluent began in February 1989, and sampling of storm water runoff will begin when GJPORAP activities are completed at the South Pond area.

3.1.2.2.2 *Sampling Plan*

The liquid effluent discharged into the sanitary sewer system currently is sampled monthly at manhole #12 (Figure 3-1). Because this location is upstream of three office building outflows, construction is under way to develop a site where all Facility outflows can be sampled. Samples collected from the sewer effluent will be analyzed for the constituents in Table 3-3, which also lists reporting limits for each of the analytes. The list of constituents was chosen on the basis of the Industrial Pretreatment Permit requirements and in response to the need for a baseline of general effluent quality.

Beginning January 1993, requirements of the Industrial Pretreatment Permit renewal will be incorporated into the GJPO's sewer sampling program. Both sampling and reporting of analytical results will be conducted quarterly, rather than monthly and semiannually, and a different set of parameters will be analyzed for. The list of parameters and their associated daily maximum values, effective as of January 1, 1993, is in Table 3-4.

The storm water effluent will be sampled manually from the outfall to the South Pond (Figure 3-1) and will be analyzed for the constituents recommended by the *Guidance Manual for the Preparation of NPDES Permit Applications for Storm Water Discharges Associated with Industrial Activity* (US-EPA 1991). Although sampling and monitoring of storm water runoff is not required by federal or state regulations, characterization of the effluent would be a best management practice. Effluent will be sampled during representative storm events and will be analyzed for the analytes listed in Table 3-5. All samples will be collected and analyzed in accordance with the test methodologies described in 40 CFR 136.

Table 3-3. Sewer Effluent Analytes and Respective Reporting Limits, GJPO Facility

Constituent	Reporting Limit
Nonradiological	
Biological Oxygen Demand	10 mg/L
Chromium/Total	0.010 mg/L
Chemical Oxygen Demand	1 mg/L
Copper/Total	0.025 mg/L
Cyanide	0.020 mg/L
Lead/Total	0.005 mg/L
Mercury/Total	0.0002 mg/L
Nickel/Total	0.040 mg/L
Oil and Grease	5 mg/L
PCBs	none defined
pH	0.01 unit
Phenols	0.005-0.05 mg/L
Silver	0.010 mg/L
Total Dissolved Solids	10 mg/L
Total Organic Carbon	0.10 mg/L
Total Organic Halides	10 μg/L
Total Suspended Solids	5 mg/L
Zinc/Total	0.020 mg/L
Radiological	
Gross Alpha	1.0 pCi/L[a]
Gross Beta	1.0 pCi/L[a]

[a]Value expressed is the typical reporting limit. The actual reporting limit varies with the total dissolved solids concentration of the effluent.

Table 3-4. Pollutants and Discharge Limitations Established by the Industrial Pretreatment Permit Renewal, Effective January 1, 1993

Pollutant	Daily Maximum Limit	Type of Sample
Biological Oxygen Demand	No limit	Composite
Total Suspended Solids	No limit	Composite
Total Dissolved Solids	No limit	Composite
Ammonia	No limit	Composite
Temperature	40°C or 104°F	Grab
pH	6.5 - 9.5	Grab
Oil and Grease	50 mg/L	Grab
Silver	0.43 mg/L	Grab
PCBs	0.002 mg/L	Grab
Flow[a] (Identify the approved method of measurement used)		

[a]Flow measurements: the GJPO shall submit information showing the measured average daily and maximum daily flow in gallons/day discharged.

Table 3-5. Storm Water Effluent Analytes and Respective Reporting Limits, GJPO/GJPORAP

Analyte	Reporting Limit
pH	0.01 unit
Biological Oxygen Demand	10 mg/L
Chemical Oxygen Demand	1 mg/L
Total Suspended Solids	5 mg/L
Total Phosphorus	0.5 mg/L
Nitrate plus Nitrite Nitrogen	0.02 mg/L
Total Kjeldahl Nitrogen	1 mg/L

Procedures and equipment for sewer effluent sampling are described in the *Sampling and Analysis Plan for Environmental Monitoring* (Chem-Nuclear Geotech, Inc. 1992a). Sampling and analysis procedures for storm water sampling will be developed before sampling begins. Effluent samples will be analyzed by the Geotech Analytical Chemistry Laboratory, with the exception of biological oxygen demand, chemical oxygen demand, total organic halides, and Kjeldahl nitrogen samples, which will be analyzed by a subcontracted laboratory. The Geotech Analytical Chemistry Laboratory will follow the procedures outlined in the *Analytical Chemistry Laboratory Handbook of Analytical and Sample Preparation Methods* (Chem-Nuclear Geotech, Inc. 1992e). The handbook prescribes the precision of each of the analytical techniques and the methodology and reporting limits used by the laboratory. Subcontracted laboratories will follow procedures described in *Standard Methods for the Examination of Water and Waste* (American Public Health Association and others 1985) for the analysis of biological oxygen demand, chemical oxygen demand, and Kjeldahl nitrogen; total organic halides samples will be analyzed according to EPA Method 9020 (US-EPA 1986).

QA and QC measures will be implemented during all sampling and analysis activities. The precision and accuracy of the sample results will be determined by the use of field and laboratory QC measures. Field QC will be accomplished by the collection and analysis of field duplicates (one sample semiannually, for a 20 percent sampling frequency). Laboratory QC will be accomplished by the analysis of blind duplicates, spikes, spike duplicates, method blanks, and calibration standards when applicable to the analytical method being performed at a frequency in accordance with the *Analytical Chemistry Laboratory Administrative Plan and Quality Control Methods* (Chem-Nuclear Geotech, Inc. 1992f). Details of the QA program are presented in Section 8.0 and Appendix A of this document.

3.1.2.2.3 *Data Management*

The Data Manager, appointed by the Geotech Project Manager, will maintain a data base for the liquid effluent monitoring program. All documentation, such as laboratory reports and Industrial Pretreatment Permit reports, will be centralized in a permanent project file by the Waste Management subsection of the Environmental Services Section within Geotech. In addition, all reports and data will be stored in a permanent project file in Geotech's Records Management Section.

3.1.2.2.4 *Data Analysis/Reporting Format*

Data will be analyzed to determine if the monitoring objectives have been met (Section 3.1.2.2.1). Only data of known quality will be used for determining whether DQOs have been met. The sewer effluent values measured in the month before the reporting due date will be compared to the threshold limits established by the Industrial Pretreatment Permit (listed in Table 3-2, effective until January 1, 1993; listed in Table 3-4, effective after January 1, 1993). Compliance with the threshold limits will be achieved if every measured value falls below the threshold value. The collected data will be internally reviewed by the Waste Management subsection quarterly and will be submitted in a tabular format to the city of Grand Junction semiannually by January 31 and July 31. After January 1, 1993, quarterly reports will be submitted to the city of Grand Junction by April 30, July 31, October 31, and January 31.

3.1.2.3 Responsible Organizations

The DOE-GJPO Manager is responsible for ensuring compliance with the Industrial Pretreatment Permit. Routine sample collection and data evaluation are delegated by the Geotech Program Manager to the Manager of Environmental Services. (An organization chart is provided in Appendix A).

3.1.3 MMTS

There is no liquid radiological or nonradiological effluent associated with the MMTS at this time.

3.2 ENVIRONMENTAL SURVEILLANCE

3.2.1 Regulatory Requirements

Surface water environmental surveillance programs at the GJPO, GJPORAP, and MMTS are conducted to comply with all ARARs outlined in Table 3-6.

3.2.2 GJPO/GJPORAP

Surface waters at or near the GJPO Facility include the Gunnison River, the North and South Ponds, and the Dike Ditch. The Gunnison River is immediately adjacent to the Facility and flows along the west boundary of the property. The North Pond and Gunnison River perennially contain water, while the South Pond and the Dike Ditch are dry during drought years.

The North and South Ponds and Dike Ditch are recharged by the shallow alluvial aquifer underlying the Facility and exhibit some of the same characteristics as the ground water. Like the ground water, these surface waters are contaminated by the leached products of uranium mill tailings. The Gunnison River, which receives discharge from the alluvial aquifer, is not measurably affected by the mill tailings contaminants because of surface water dilution. A more complete description of surface water sources is available in the GJPO RI/FS--EA (UNC Geotech 1989a).

3.2.2.1 Historical Surface Water Monitoring

Monitoring of surface water quality at the GJPO began in 1979 and is ongoing. The main goal of the monitoring was to characterize the type and extent of contamination within the North and South Ponds, the Dike Ditch, and the Gunnison River. Generally, the surface water sources were "grab sampled" at the shorelines semiannually or quarterly. The Gunnison River was sampled upstream of the Facility for background concentrations, and the results were compared with those of samples taken adjacent to

Table 3-6. ARARs for Surface Water Environmental Surveillance

Standard, Requirement, Criterion, or Limitation	Citation	Description
<u>ARARs Common to the GJPO, GJPORAP, and MMTS</u>		
General Environmental Protection Program	DOE 5400.1 Chapter IV Part 8d	1. Ambient water quality monitoring should be conducted through a network of fixed stations from which data will establish well-defined histories of the physical and chemical conditions of local bodies of water. The data obtained from this network should be coordinated with other monitoring activities. 2. Analysis from a fixed station monitoring network should support: a. Characterizing and defining trends in the physical and chemical condition of surface waters. b. Establishing baselines of water quality. c. A continuing assessment of water pollution control programs. d. Identifying new water quality problems. e. Detecting, characterizing, and reporting unplanned releases and their effects on the environment. 3. Monitoring stations should be operated and maintained through established procedures. 4. Types of sampling performed should depend upon local conditions and the variability of stream characteristics and water quality.

Table 3-6 (continued). ARARs for Surface Water Environmental Surveillance

Standard, Requirement, Criterion, or Limitation	Citation	Description
General Environmental Protection Program (continued)	DOE 5400.1 Chapter IV Part 8d	5. The monitoring frequency at a fixed network will be a function of the variability of the chemical, physical, and biological conditions of the water body. 6. Ambient water quality monitoring will serve to confirm compliance with the Clean Water Act.
Radiation Protection of the Public and Environment	DOE 5400.5 Chapter I Part 8a	Demonstrations of compliance with requirements of this order generally will be based upon calculations that use information obtained from monitoring and surveillance programs.
Radiological Effluent Monitoring and Environmental Surveillance	DOE Environmental Regulatory Guide Chapter 5	1. An evaluation will be conducted and used as the basis for establishing an environmental surveillance program. The extent of the environmental surveillance program will be based on the applicable regulations, the hazard potential of the effluents, the quantities and concentrations of effluents, the specific public interest, and the nature of potential or actual impacts on air, land, biota, and water. The results of the evaluation shall be documented in the Environmental Monitoring Plan to show: a. Environmental measurement and sampling locations used for determining ambient environmental levels resulting from Facility operations; b. Procedures and equipment needed to perform the measurement and sampling;

Table 3-6 (continued). ARARs for Surface Water Environmental Surveillance

Standard, Requirement, Criterion, or Limitation	Citation	Description
Radiological Effluent Monitoring and Environmental Surveillance (continued)	DOE Environmental Regulatory Guide Chapter 5	c. Frequency and analyses required for each measurement and sampling location; d. Minimum detection level and accuracy; and e. Quality assurance components 2. Provisions shall be made for the detection and quantification of unplanned releases of radionuclide to the environment. 3. DOE Field Office and contractor staff shall ensure that ground water monitoring plans are consistent with State and regional EPA ground water monitoring requirements under RCRA and CERCLA to avoid unnecessary duplication.
Data Analysis and Statistical Treatment	DOE Environmenal Regulatory Guide Chapter 7	1. The statistical techniques used to support the concentration estimates, to determine their corresponding measures of reliability, and to compare radionuclide data between sampling and/or measurement points and times shall be designed with consideration of the characteristics of environmental data. 2. Documented and approved sampling, sample-handling, analysis, and data management techniques shall be used to reduce the variability of results. 3. The level of confidence in radiological data shall be estimated by analyzing blanks and spiked pseudo-samples and by comparing the resulting concentration estimates to the known concentrations in those samples.

Table 3-6 (continued). ARARs for Surface Water Environmental Surveillance

Standard, Requirement, Criterion, or Limitation	Citation	Description
Data Analysis and Statistical Treatment (continued)	DOE Environmental Regulatory Guide Chapter 7	4. The precision of radionuclide analytical results shall be reported as a range, a variance, a standard deviation, a standard error, and/or a confidence interval. 5. Outliers shall be excluded from the data only after investigation confirms that an error has been made in the sample collection, preparation, measurement or data analysis process.
<u>ARAR Specific to the GJPO/GJPORAP</u>		
The Basic Standards and Methodologies for Surface Water, and Classifications and Numeric Standards for Gunnison and Lower Delores River Basins	Colorado Dept. of Health, Water Quality Control Commission (5 CCR 1002-8)	Establishes basic standards, an antidegratation rule and a system for State of Colorado surface waters. Also establishes State water quality standards for specific stream segments
<u>ARARs Specific to the MMTS</u>		
Definitions for Water Pollution Rules and General Requirements	Title 26, Chapter 11, Utah Code Annotated (R448-1, U.A.C)	The statute and rules set forth the definitions and general requirements for the Utah Water Quality Standards.
State of Utah Water Quality Standards	Title 26, Chapter 11, Utah Code Annotated (R448-2, U.A.C)	Establishes a classification system for surface waters within the State of Utah and standards for specific stream segments.

and downstream of the Facility. Constituents that were measured in surface waters during this period are in Table 3-7.

Table 3-7. Water Quality Constituents Analyzed in Surface Water Samples for the GJPO/GJPORAP from 1979 to Present

Nonradiological Constituents		Radiological Constituents
Aluminum	Manganese	Gross Alpha
Ammonium-Nitrogen	Mercury	Gross Beta
Arsenic	Molybdenum	Radium-226
Barium	Nickel	Radium-228
Beryllium	Nitrate-Nitrogen	Thorium-230
Cadmium	Nitrite-Nitrogen	Thorium-232
Calcium	pH	Uranium-234
Chloride	Phosphate	Uranium-238
Chromium	Potassium	
Cobalt	Selenium	
Copper	Silver	
Dissolved Oxygen	Specific Conductance	
Fecal Coliform	Sulfate	
Fluoride	Total Dissolved Solids	
Iron	Total Organic Carbon	
Lead	Uranium	
Magnesium	Vanadium	
	Zinc	

Like the ground water that is contaminated by the leached products of mill tailings, water in the North Pond, South Pond, and Dike Ditch consistently has contained higher-than-background concentrations of uranium, selenium, arsenic, molybdenum, vanadium, and sulfate. Higher-than-background levels of radium-226 were measured regularly in the Dike Ditch, when it contained water.

Although tailings-contaminated ground water discharges into the Gunnison River, water samples taken adjacent to and downstream of the Facility have shown no increases in contaminants compared with upstream samples. Upstream water quality samples consistently have contained low or nondetectable levels of mill tailings-related constituents. In the 10 years of monitoring, only one grab sample (October 1981) showed any significant difference between upstream water quality and downstream water quality. In that sample, gross alpha particle activity increased from 9 pCi/L in the upstream sample to 21 pCi/L in the downstream sample (Korte and Thul 1982).

Since 1987, measured values within the Gunnison River have been compared to the surface water quality standards established for the stream segment by the Colorado Department of Health. Only manganese, sulfate, and pH have exceeded state standards. These same constituents were occasionally measured at higher-than-standard levels at all river sampling locations and were not necessarily an indication of the Facility's influence on the river.

More information about the annual surface water monitoring programs and results is in the Environmental Monitoring Reports for calendar years 1979 through 1991 (Bendix 1980; Korte and Thul 1981, 1982, 1983, 1984; Korte and Wagner 1985, 1986; Sewell and Spencer 1987; UNC Geotech 1988b, 1989c, 1990d; Chem-Nuclear Geotech, Inc. 1991c, 1992g).

3.2.2.2 Planned Surface Water Monitoring

3.2.2.2.1 *Monitoring Objectives*

The objectives of the surface water monitoring program at the GJPO Facility are

1. to establish a baseline of upstream water quality conditions within the Gunnison River with which to compare adjacent and downstream samples;

2. to characterize the type and extent of contamination in surface water sources;

3. to verify compliance with state surface water quality standards; and

4. to detect changes in water quality resulting from remedial action.

The historical surface water monitoring program has accomplished the first, second, and third monitoring objectives (see Section 3.2.2.1). Current and future monitoring will focus on the third and fourth objectives.

The Colorado Water Quality Control Act prohibits "injuries to the beneficial uses made of state waters," and establishes water quality standards for stream segments within Colorado. Applicable to the segment of the Gunnison River adjacent to the GJPO Facility are four state use classifications--(1) Recreation Class I, (2) Cold Water Aquatic Life Class I, (3) Domestic Water Supply, and (4) Agriculture. The most restrictive numeric standards associated with these classifications are listed in Table 3-8.

All of the constituents in Table 3-8, with the exception of NH_3, cyanide, boron, dissolved oxygen, and the organic compounds, were measured within the Gunnison River at some time during the last 12 years. Of these measured constituents, only fecal coliform, manganese, sulfate, and pH have exceeded the standards established by the state (standard exceedances occurred both upstream and downstream of the GJPO Facility and were not associated with activities or contamination on the Facility). Future surface

Table 3-8. Colorado Department of Health, Water Quality Control Division, Surface Water Quality Standards for the Gunnison River

Constituent	Maximum Concentration[a]		Constituent	Maximum Concentration	
Uranium	40	pCi/L	Aldrin	0.003	μg/L
Arsenic	0.360	mg/L	Dieldrin	0.003	μg/L
Cadmium	0.021	mg/L	DDT (DDD and DDE)	0.001	μg/L
Chromium (+3)	0.0696	mg/L	Endrin	0.004	μg/L
Chromium (+6)	0.011	mg/L	Heptachlor	0.001	μg/L
Copper	0.042	mg/L	Lindane	0.01	μg/L
Iron (soluble)	0.300[b]	mg/L	Methoxychlor	0.03	μg/L
Iron (total)	1.000	mg/L	Mirex	0.001	μg/L
Manganese (soluble)	0.050[b]	mg/L	Toxaphene	0.005	μg/L
Manganese (total)	1.000	mg/L	Demeton	0.1	μg/L
Mercury	0.0001	mg/L	Endosulfan	0.003	μg/L
Nickel	0.295	mg/L	Guthion	0.01	μg/L
Selenium	0.017	mg/L	Malathion	0.1	μg/L
Silver	0.001	mg/L	Parathion	0.04	μg/L
Zinc	0.372	mg/L	2,4-D	0.1	mg/L
NH_3 (30-day)	0.02	mg/L	PCB	0.001	μg/L
Residual Cl_2	0.003	mg/L	Chlorphenol	0.001	mg/L
Cyanide (free)	0.005	mg/L	Monohydric phenol	0.001	mg/L
S as H_2S	0.002	mg/L	Benzidine	0.01	μg/L
Boron	0.75	mg/L			
Nitrite	0.05	mg/L			
Nitrate	10.0	mg/L			
Chloride	250.0	mg/L			
Sulfate	250.0	mg/L			
Lead	0.032	mg/L			
Dissolved Oxygen	6.0	mg/L			
pH	6.5-9.0	units			
Fecal coliform	200/100 ml				

[a] The standards for metals are stated as dissolved, unless otherwise indicated, and are those associated with the Cold Water Aquatic Life Class I classification, unless otherwise indicated. A hardness value of 440 mg/L was used to calculate metal "table value standards."

[b] The listed standard is associated with the Domestic Water Supply standard.

water monitoring will focus on analyzing for the constituents that occur in concentrations above background levels in the ground water and that may contaminate the Gunnison River (see Section 4.0 for Ground Water monitoring). The monitoring will determine whether state standards are exceeded within the Gunnison River. In addition, water samples will be analyzed for total organic carbon as an "indicator" of organic compounds, and field measurements of alkalinity, pH, and specific conductance will be conducted to detect gross changes in water quality. The constituents that surface waters will be analyzed for are in Table 3-9, along with their respective reporting limits.

Table 3-9. Surface Water Quality Analytes and Respective Reporting Limits, GJPO/GJPORAP

Nonradiological Constituents	Reporting Limit	Radiological Constituents	Reporting Limit
Arsenic	0.010 mg/L	Gross alpha (excluding Radon and Uranium)	2.0 pCi/L
Barium	0.20 mg/L		
Cadmium	0.003 mg/L		
Calcium	5.0 mg/L	Radium-226	0.5 pCi/L
Chloride	0.10 mg/L	Radium-228	1.0 pCi/L
Chromium	0.010 mg/L	Uranium-234	0.5 pCi/L
Iron	0.10 mg/L	Uranium-238	0.5 pCi/L
Lead	0.003 mg/L	Thorium-230	1.0 pCi/L
Magnesium	5.0 mg/L	Thorium-232	1.0 pCi/L
Manganese	0.015 mg/L		
Molybdenum	0.050 mg/L		
Nitrate	0.01 mg/L		
Potassium	5.0 mg/L		
Selenium	0.005 mg/L		
Sodium	5.0 mg/L		
Sulfate	0.10 mg/L		
Vanadium	0.050 mg/L		
Alkalinity	None Defined		
pH	0.1 unit		
Specific Conductance	None Defined		
Total Dissolved Solids	10 mg/L		
Total Organic Carbon	0.10 mg/L		

In accordance with the fourth monitoring objective, measurements of the constituents in Table 3-9 will be used to detect changes in water quality resulting from remedial action activities. Environmental conditions at the GJPO Facility are not currently affecting the water quality of the Gunnison River, and no adverse changes are anticipated. Water quality should improve in the North Pond, South Pond, and Dike Ditch after the tailings piles on the Facility and contaminated sediments within the South Pond and Dike Ditch are removed.

3.2.2.2.2 *Sampling Plan*

The North Pond, South Pond, Dike Ditch, and Gunnison River will be sampled quarterly (March, June, September, and December) for the surface water quality constituents in Table 3-9. Quarterly sampling will allow seasonal fluctuations in the chemical concentrations to be examined and will reduce the problem of serial correlation if the data are statistically analyzed. Sampling locations are shown in Figure 3-2.

Data collection for background characterization will continue on the Gunnison River upstream of the GJPO Facility. In addition, Gunnison River samples will be collected from two sites adjacent to the Facility and from one site downstream of the Facility. Water samples will be collected with a peristaltic pump or by container immersion at a known location near the shoreline of the river. Specific procedures are described in the *Sampling and Analysis Plan for Environmental Monitoring* (Chem-Nuclear Geotech, Inc. 1992a).

Surface water samples will be analyzed by the Geotech Analytical Chemistry Laboratory or subcontracted to a qualified laboratory. Analytical procedures followed by the Geotech Analytical Laboratory will be those outlined in the *Analytical Chemistry Laboratory Handbook of Analytical and Sample Preparation Methods* (Chem-Nuclear Geotech, Inc. 1992e). The handbook describes the precision of each of the analytical techniques and the methodology and reporting limits used by the laboratory. Subcontracted laboratories will adhere to the analytical methods and detection limits prescribed by the EPA (US-EPA 1986) for evaluating solid wastes. To ensure the integrity of the samples from their collection in the field to the time of their laboratory analyses, a chain-of-custody record will be maintained for each possession transfer.

QA and QC measures will be implemented during all sampling and analysis activities. The precision and accuracy of the sample results will be determined by the use of field and laboratory QC measures. Field QC will be accomplished by the collection and analysis of field duplicates (one sample per batch or 5 percent) and equipment blanks (one sample per trip for each piece of equipment used). Laboratory QC will be accomplished by the analysis of blind duplicates, spikes, spike duplicates/ duplicates, method blanks, and calibration standards when applicable to the analytical method being performed at a frequency in accordance with the *Analytical Chemistry Laboratory Administrative Plan and Quality Control Methods* (Chem-Nuclear Geotech, Inc. 1992f). Details of the QA program are in Section 8.0 and Appendix A of this document.

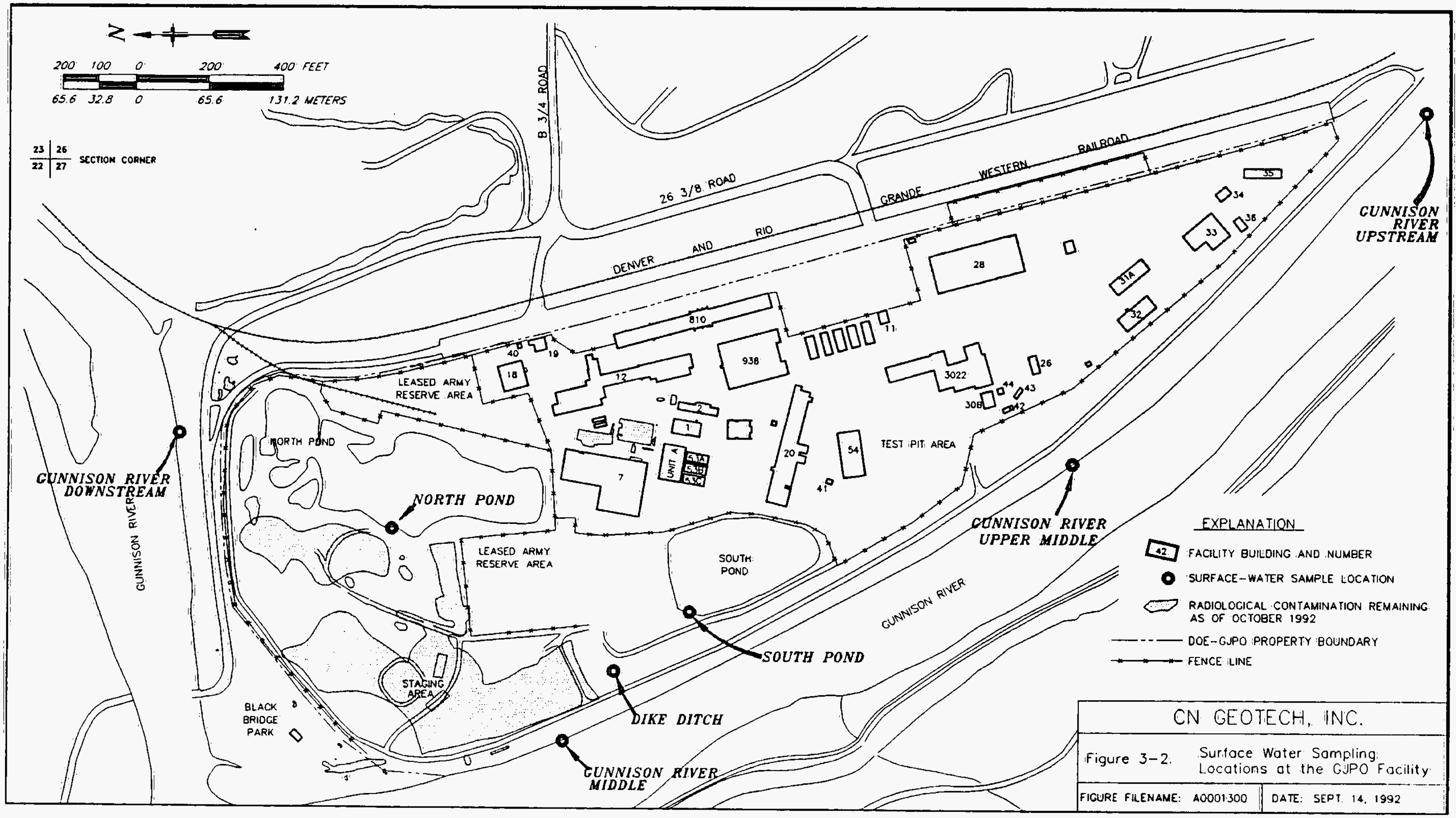

Figure 3-2. Surface Water Sampling Locations at the GJPO Facility

3.2.2.2.3 *Data Management*

The Data Manager, appointed by the Geotech Project Manager, will maintain a data base for all the surface water monitoring data. Data will be stored in an ORACLE data base package on a MicroVAX computer system and will be backed up weekly. In addition, all reports and data will be stored in a permanent project file in Geotech's Records Management Section.

3.2.2.2.4 *Data Analysis/Reporting Format*

Data will be analyzed to determine if the monitoring objectives have been met. Only data of known quality will be used to determine if DQOs are met. Measured surface water values in Table 3-9 will be compared in a graphical format with the state standards in Table 3-8. Figure 3-3 illustrates a method for graphically displaying and comparing measured water quality data with state standards. Compliance with state standards will be achieved when every constituent's measured value falls below the respective standard value. If a state standard is exceeded, an investigation will determine whether operations at the GJPO Facility were responsible for the exceedance. All monitoring data will be tabulated and reviewed quarterly, and a summary of the data will be presented in the Annual Site Environmental Report.

Data will be analyzed in a time sequence to determine whether changes in water quality have taken place. Graphical displays of concentration as a function of time (Figure 3-3) for selected constituents in Table 3-9 will be the main reporting format.

Because water quality data often vary seasonally within a single year, it is sometimes difficult to distinguish real changes in concentration from natural, seasonal changes. When this situation exists, statistical analyses can be used to quantitatively determine whether apparent trends are real. Statistical analysis also has the advantage of providing scientifically defensible data. Recent literature (Harcum 1990, Ward and others 1990, Loftis and others 1987, Loftis and others 1989) suggests that nonparametric methods (methods that do not require the data to be normally distributed) for analyzing data are the most reliable. The Mann-Kendall test, which evaluates the significance of an apparent increase or decrease in concentration over time, may be used to determine whether trends exist in the surface water quality data. The methodology for the test is discussed at length in Gilbert (1987) and is included as Appendix B in this document. A rate of change also may be calculated using the Sen Slope Estimate from Gilbert (1987).

For data analysis purposes, outliers will be excluded from the data *only* after an investigation confirms that an error has been made in the sample collection, preparation, measurement, or data analysis process, in accordance with DOE's *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (US-DOE 1991). Non-detects will be recorded as one-half the detection limit for statistical analysis (Ward and others 1990, Loftis 1990).

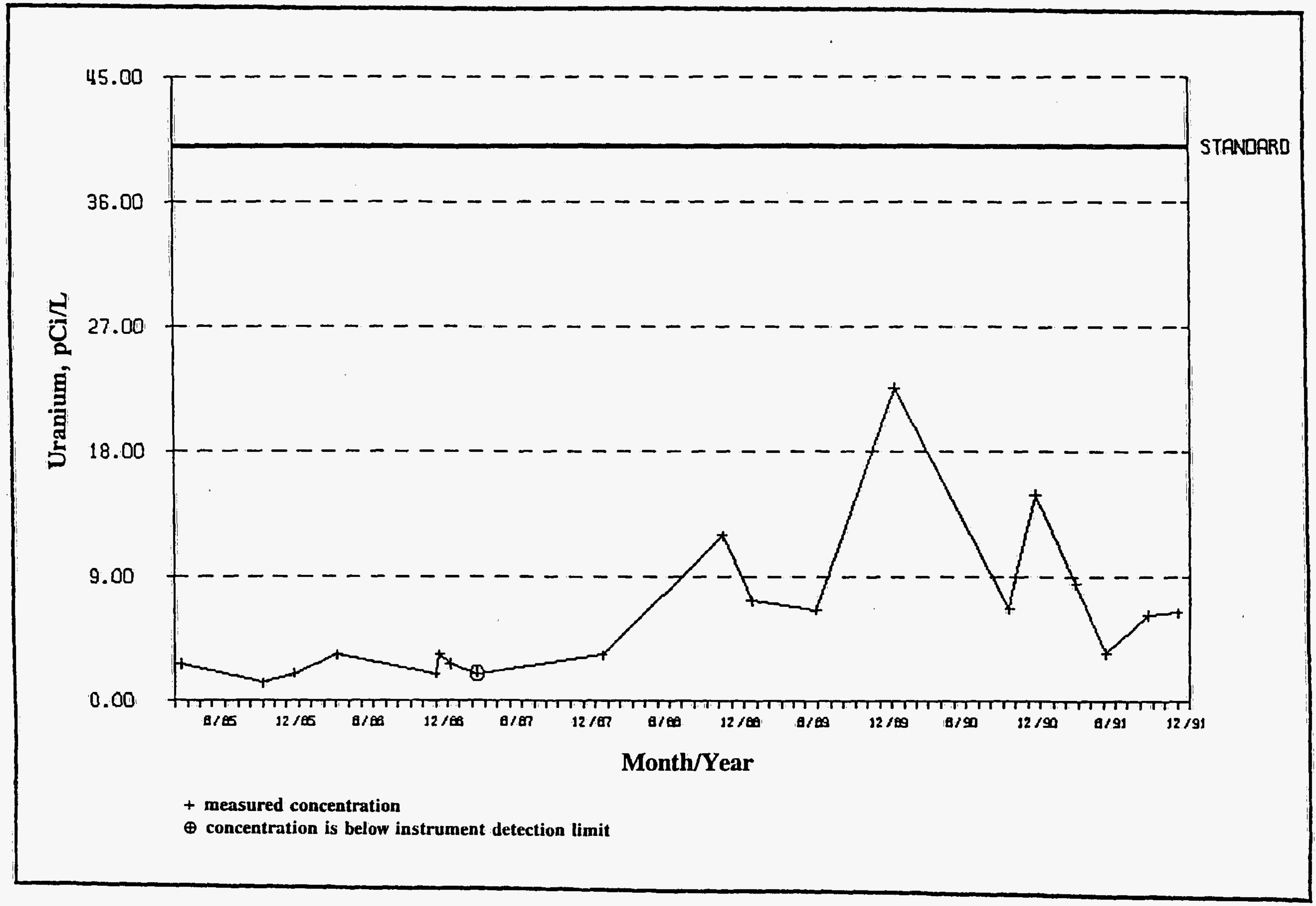

Figure 3-3. Example Illustrating Graphical Display of Water Quality Data

3.2.2.3 Responsible Organizations

It is the responsibility of the DOE-GJPO Manager to direct the surface water monitoring effort. The Geotech Program Manager directs the Geotech Project Manager to implement the surface water monitoring program. Currently, this responsibility resides with the Environmental Services Section. The Geotech Project Manager will be responsible for planning and budgeting surface water projects, monitoring surface water project activities, conducting data evaluation, and preparing reports. To accomplish these tasks, the Project Manager will assign surface water projects to personnel within Geotech who possess the technical expertise to perform the required activities, or the work will be subcontracted to outside organizations. (An organization chart is provided in Appendix A).

3.2.3 MMTS

Several perennial and intermittent surface water sources are located on and near the Monticello Millsite. Perennial sources on the site include Montezuma Creek, which flows through the middle of the property; the Carbonate Seep, located at the southeast corner of the Carbonate Tailings pile; and the drainage between the Carbonate and Vanadium Piles (designated W-2 in Figure 3-4).

Montezuma Creek historically has been sampled upstream of the millsite at several locations (including W-3 in Figure 3-4), on site at five different locations along the creek, and downstream at three locations designated as W-4 (0.8 km downstream of the millsite boundary), the Sorenson Site (1.6 km downstream of the boundary), and the Montezuma Canyon Site (about 9.6 km downstream of the boundary) (see Figure 3-5). In November 1992, nine sampling locations will be added along Montezuma Creek: three locations upstream of the millsite (SW92-01, -02, and -03), two locations on site (SW92-04, -05), and four locations downstream of the millsite (SW92-06, -07, -08, and -09).

The Carbonate Seep supports riparian vegetation and is typically the only on-site seep that contains water during the dry season. This seep feeds the drainage that flows perennially between the Carbonate and Vanadium Piles.

Intermittent water sources include seeps, ponds, and ditches on and near the millsite property. The seeps are located south of the Vanadium Pile and east of the Acid Pile and usually contain water only in the spring months. A diversion ditch is located north of the East Tailings Pile and carries water intermittently into Montezuma Creek. Another ditch crosses the northwest corner of the millsite property and is used to transport irrigation water. To the east of the millsite is the Somerville pond, which is fed by water diverted from Montezuma Creek and used for stock watering. An additional water source, the North Drainage, is located northwest of the Vanadium Tailings Pile and collects surface runoff and seeping ground waters.

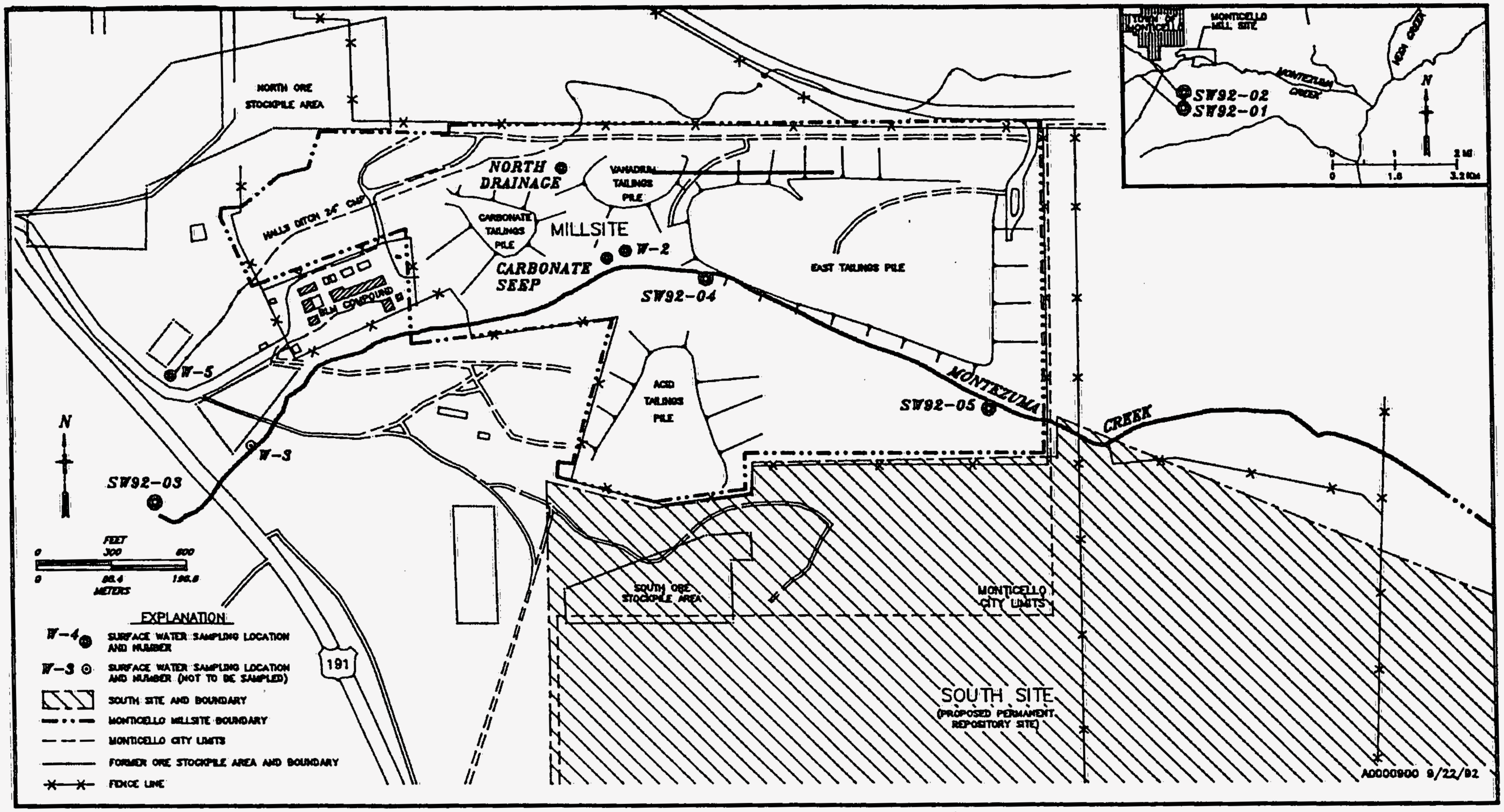

Figure 3-4. Surface Water Sampling Locations On Site and Upgradient of the Monticello Millsite

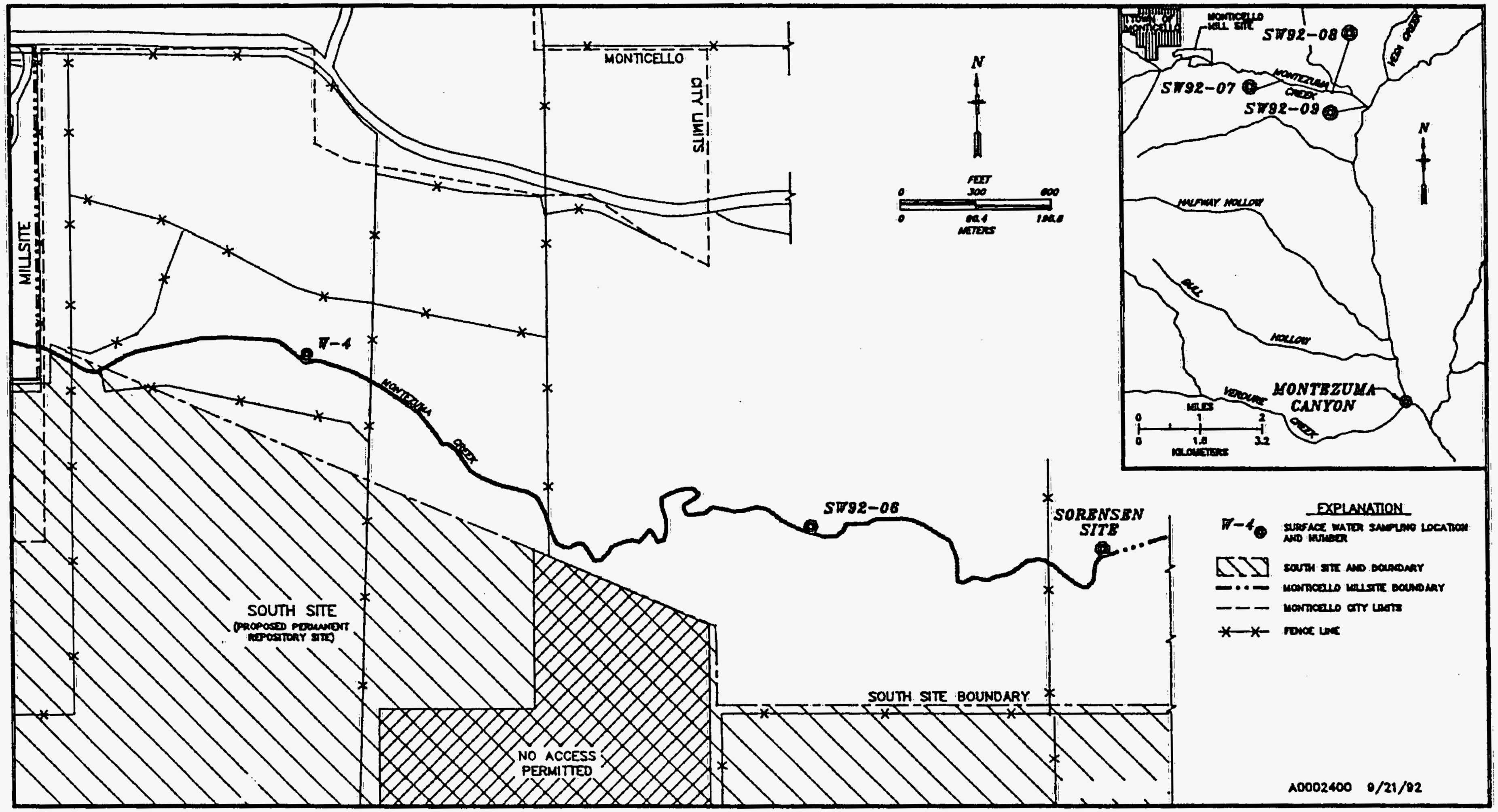

Figure 3-5. Surface Water Sampling Locations Downgradient of the Monticello Millsite

More complete descriptions of the surface water sources affected by the Monticello Millsite are in the *Monticello Mill Tailings Site, Operable Unit III, Surface- and Ground-Water Remedial Investigation/Feasibility Study Work Plan* (Chem-Nuclear Geotech, Inc. 1992h).

3.2.3.1 Historical Surface Water Monitoring

Monitoring of Montezuma Creek began in 1955, when it was discovered that liquid effluent from the salt roast/carbonate leach plant was affecting water quality within the creek. At the same time, it was recognized that radium levels in the water and stream sediments were increasing as a result of uranium mill operations. Studies were initiated in the following years to develop methods for dealing with these problems. Monitoring continued sporadically over the years until 1979, when the present surface water monitoring program began.

From 1979 to November 1992, all the surface water sources described in Section 3.2.3, which are located on, upstream, and downstream of the millsite, were sampled, and samples were analyzed for a range of water quality constituents to assess the type and extent of contamination. The constituents analyzed for during this period were the same as those analyzed for at the GJPO (with the exception of fecal coliform and thorium-230) and are in Table 3-7 in Section 3.2.2.1. Background surface water quality data were gathered from Montezuma Creek upstream of the millsite at several sampling sites, including the W-3 site shown in Figure 3-4. Analyses showed that the samples contained low or nondetectable levels of the trace elements usually associated with uranium mill tailings.

On the millsite property, samples from all of the surface water sources were contaminated with elements leached from the mill tailings piles. Higher-than-background concentrations of uranium, arsenic, molybdenum, and vanadium were found in samples from surface water sources on and downstream of the millsite. Contamination from the uranium mill tailings was found in samples from Montezuma Creek as far as 9.6 km below the millsite property. The highest concentrations of mill-tailings-related contaminants typically were in samples from the Carbonate Seep, W-2, and Sorenson sampling sites (Figures 3-4 and 3-5).

The specific sites monitored during the past years have varied. Generally, background samples were taken upstream of the millsite, and samples showing contamination were obtained at several sites on and downstream of the millsite. Sampling intervals have varied from semiannual to quarterly. More information concerning the annual monitoring programs is in the Environmental Monitoring Reports for calendar years 1979 through 1991 (Bendix 1980; Korte and Thul 1981, 1982, 1983, 1984; Korte and Wagner 1985, 1986; Sewell and Spencer 1987; UNC Geotech 1988a, 1989b, 1990b; Chem-Nuclear Geotech, Inc. 1991b, 1992d).

3.2.3.2 Planned Surface Water Monitoring

3.2.3.2.1 *Monitoring Objectives*

The objectives of the surface water monitoring program for the MMTS are

1. to compare upstream water quality conditions within Montezuma Creek to conditions on and downstream of the millsite;

2. to characterize the type and extent of contamination in surface water sources;

3. to verify compliance with state surface water quality standards; and

4. to detect changes in water quality resulting from remedial action.

The historical surface water monitoring program has provided data for accomplishing the first and second monitoring objectives. Current and future monitoring will focus on all four of the objectives.

3.2.3.2.2 *Sampling Plan*

Surface water samples will be collected from three locations upgradient of the millsite (SW92-01, SW92-02, and SW92-03), six locations on the millsite (W-5, North Drainage, Carbonate Seep, W-2, SW92-04, and SW92-05), and seven locations downgradient of the millsite (Sorensen Site, W-4, Montezuma Canyon, SW92-06, SW92-07, SW92-08, and SW92-09), as shown in Figures 3-4 and 3-5. Sampling will occur four times during fiscal year 1993, after which a new sampling schedule will be established. Constitutents that will be analyzed for at surface water locations upgradient of and on the millsite are listed in Table 3-10. With the exception of organic compounds, downgradient samples also will be analyzed for these constituents during the first round of sampling. Depending on the results of the first-round sampling, downgradient samples from later rounds may be investigated for organic compounds.

Sampling procedures, QA and QC measures, laboratory analysis procedures, and reporting limits for analytical parameters are described in the *Monticello Mill Tailings Site, Operable Unit III, Surface- and Ground-Water Remedial Investigation/Feasibility Study Field Sampling Plan* (Chem-Nuclear Geotech, Inc. 1992c) and *Quality Assurance Project Plan* (Chem-Nuclear Geotech, Inc. 1992i).

3.2.3.2.3 *Data Management*

Data storage and management will be the same as that described for the GJPO/GJPORAP (Section 3.2.2.2.3).

Table 3-10. Surface Water Quality Analytes, MMTS

Analytical Parameters	Analytes
Volatile Organic Compounds	Target Compound List[a]
Semivolatile Organic Compounds	Target Compound List[a]
Pesticides/PCBs	Aldrin Alpha-BHC Beta-BHC Delta-BHC Gamma-BHC (lindane) Alpha-Chlordane Gamma-Chlordane 4,4'-DDD 4,4'-DDE 4,4'-DDT Dieldrin Endosulfan Sulfate Endrin Endrin Aldehyde Heptachlor Heptachlor Epoxide Methoxychlor Toxaphene Aroclor 1016 Aroclor 1221 Aroclor 1232 Aroclor 1242 Aroclor 1248 Aroclor 1254 Aroclor 1260
Herbicides	2,4-D 2,4-DB 2,4,5-TP (Silvex) Dalapon 2,4,5-T Dichloroprop

[a]Target Compound List volatiles and semivolatiles are listed in the *Monticello Mill Tailings Site, Operable Unit III, Surface- and Ground- Water Remedial Investigation/ Feasibility Study Field Sampling Plan* (Chem-Nuclear Geotech, Inc. 1992c).

Table 3-10 (continued). Surface Water Quality Analytes, MMTS

Analytical Parameters	Analytes
Major Anions	Chloride Fluoride Nitrate Nitrite Nitrate and Nitrite Sulfate
Major Cations	Ammonium Calcium Magnesium Potassium Sodium
Metals	Aluminum Antimony Arsenic Barium Boron Beryllium Cadmium Chromium Copper Cyanide Iron Lead Manganese Mercury Molybdenum Nickel Selenium Silver Strontium Thallium Vanadium Zinc
Total Dissolved Solids	TDS

Table 3-10 (continued). Surface Water Quality Analytes, MMTS

Analytical Parameters	Analytes
Radionuclides	Gross Alpha Gross Beta Lead-210 Polonium-210 Radium-226 Radium-228 Thorium-230 Thorium-232 Uranium-234 Uranium-238 Radon-222

3.2.3.2.4 *Data Analysis/Reporting Format*

Data analysis techniques and reporting formats will be the same as those described for the GJPO/GJPORAP (Section 3.2.2.2.4).

3.2.3.3 Responsible Organizations

Responsible organizations will be the same as those described for the GJPO/GJPORAP (Section 3.2.2.3).

4.0 Ground Water

4.0 GROUND WATER

4.1 EFFLUENT MONITORING

All ground water monitoring for the GJPO, GJPORAP, and MMTS is conducted under the environmental surveillance program.

4.2 ENVIRONMENTAL SURVEILLANCE

4.2.1 Regulatory Requirements

Guidance and requirements for a ground water monitoring plan are in Table 4-1 as ARARs.

4.2.2 GJPO/GJPORAP

Historically, the ground water monitoring program has focused on the alluvial aquifer, which has been contaminated by the leached products of uranium mill tailings located on the GJPO Facility. Thickness of the alluvial aquifer is about 6 to 7.5 meters (20 to 25 feet), and its hydraulic conductivity is approximately 9 meters/day (30 ft/day). The aquifer is recharged primarily by the high flows of the Gunnison River and secondarily by precipitation. Ground water enters the alluvial aquifer from the Gunnison River along the southern perimeter of the GJPO. During periods of high river runoff, ground water flow direction is towards the middle of the aquifer; during periods of normal river runoff, flow direction is towards the north. Ground water is discharged into the Gunnison River along the north and west boundaries of the GJPO.

Underlying the alluvial aquifer is the Morrison Formation, which is composed mainly of red, green, and gray shales. The Morrison serves as an aquitard beneath the Facility, as it inhibits downward ground water flow and prevents communication between the alluvial aquifer and the underlying Entrada Sandstone aquifer.

Complete descriptions of the hydrogeologic setting and extent of the contaminant plume within the alluvial aquifer are in the *GJPO Ground Water Protection Management Plan* (UNC Geotech 1990e) and the *Final Remedial Investigation/Feasibility Study--Environmental Assessment for the U.S. Dept. of Energy GJPO Facility* (UNC Geotech 1989a).

4.2.2.1 Historical Ground Water Monitoring

Monitoring began in 1979 with water quality sampling of two on-site wells--the north and south wells--completed in the alluvial aquifer. A range of water quality constituents was analyzed for, including heavy metals, radiological constituents, inorganic ions, total

Table 4-1. ARARs for Ground Water Environmental Surveillance

Standard, Requirement, Criterion, or Limitation	Citation	Description
<u>ARARs Common to the GJPO, GJPORAP, and MMTS</u>		
General Environmental Protection Program	DOE 5400.1 Chapter IV Part 9	1. Ground water that is or could be affected by DOE operations shall be monitored to determine and document the effects of operations on ground-water quality and demonstrate compliance with applicable regulations. 2. A ground water monitoring plan shall be developed as a specific element of all environmental monitoring plans. 3. The ground water monitoring plan shall identify all DOE requirements and regulations applicable to ground water protection and will include monitoring strategy. 4. General requirements of ground water monitoring programs include conducting monitoring on site and in the vicinity of DOE facilities to a. Obtain data for the purpose of determining baseline conditions of groundwater quality and quantity; b. Demonstrate compliance with and implementation of all applicable regulations and DOE orders; c. Provide data to permit the early detection of groundwater pollution or contamination.

Table 4-1 (continued). ARARs for Ground Water Environmental Surveillance

Standard, Requirement, Criterion, or Limitation	Citation	Description
General Environmental Protection Program (continued)	DOE 5400.1 Chapter IV Part 9	d. Provide a reporting mechanism for detected groundwater pollution or contamination. e. Identify existing and potential groundwater contamination sources and to maintain surveillance of these sources; f. Provide data upon which decisions can be made concerning land disposal practices and the management and protection of ground water resources. 5. The elements of the ground water monitoring program shall be specified (sampling plan, sampling, analysis, and data management), as shall the analysis or purpose for selecting these elements. 6. Site-specific characteristics shall determine monitoring needs.
DOE Groundwater Quality Protection Strategy	DOE Draft Notice 5400.AA	Establishes DOE's framework for the protection of ground-water quality at and near its facilities. The protection strategy includes several key elements, some of them pertaining to monitoring. The monitoring elements include a. systematically document past and present practices at DOE facilities that may affect ground-water quality.

Table 4-1 (continued). ARARs for Ground Water Environmental Surveillance

Standard, Requirement, Criterion, or Limitation	Citation	Description
DOE Ground Water Quality Protection Strategy (continued)	DOE 5400.AA	b. Characterize and monitor, through use of appropriate methods, ground water systems under-lying DOE facilities whose operations may affect ground-water quality; determine and document the effects of DOE operations on ground-water quality and quantity. c. Implement remedial measures to clean up existing ground water commensurate with appropriate standards.
Radiological Eff uent Monitoring and Environmental Surveillance	DOE Environmental Regulatory Guide Chapter 5	1. An evaluation shall be conducted and used as the basis for establishing an environmental surveillance program. The extent of the environmental surveillance program is to be based on the applicable regulations, the hazard potential of the effluents, the quantities and concentrations of effluents, the specific public interest, and the nature of potential or actual impacts on air, land, biota, and water. The results of the evaluation shall be documented in the Environmental Monitoring Plan to show: a. Environmental measurement and sampling locations used for determining ambient environmental levels resulting from facility operations; b. Procedures and equipment needed to perform the measurement and sampling;

Table 4-1 (continued). ARARs for Ground Water Environmental Surveillance

Standard, Requirement, Criterion, or Limitation	Citation	Description
Radiological Effluent Monitoring and Environmental Surveillance (continued)	DOE Environmental Regulatory Guide Chapter 5	c. Frequency and analyses required for each measurement and sampling location; d. Minimum detection level and accuracy; and e. Quality assurance components. 2. Provisions shall be made for the detection and quantification of unplanned releases of radionuclides to the environment. 3. DOE Field Office and contractor staff shall ensure that ground water monitoring plans are consistent with State and regional EPA ground water monitoring requirements under RCRA and CERCLA to avoid unnecessary duplication.
Data Analysis and Statistical Treatment	DOE Environmental Regulatory Guide Chapter 7	1. The statistical techniques used to support the concentration estimates, to determine their corresponding measures of reliability, and to compare radionuclide data between sampling and/or measurement points and times shall be designed with consideration of the characteristics of environmental data. 2. Documented and approved sampling, sample handling, analysis, and data management techniques shall be used to reduce the variability of results.

Table 4-1 (continued). ARARs for Ground Water Environmental Surveillance

Standard, Requirement, Criterion, or Limitation	Citation	Description
Data Analysis and Statistical Treatment (continued)	DOE Environmental Regulatory Guide Chapter 7	3. The level of confidence in the data due to the radiological analyses shall be estimated by analyzing blanks and spiked samples and by comparing the resulting concentration estimates with the known concentrations in those samples.
		4. The precision of radionuclide analytical results shall be reported as a range, a variance, a standard deviation, a standard error, and/or a confidence interval.
		5. Outliers shall be excluded from the data only after investigation confirms that an error has been made in the sample collection, preparation, measurement, or data analysis process.
EPA Standards for Inactive Uranium Mill Tailings Sites	40 CFR Part 192 as amended by 52 Fed. Reg. 36000 (Sept. 24, 1987)	1. Requires DOE to establish a monitoring program to determine the extent of contamination in ground water around a processing site (Part 192.12(c)(1), Part 192.11(b)(4)).
		2. States that the possible presence of any of the inorganic or organic hazardous constituents identified in tailings or used in the processing operation should be assessed for ground water.
		3. Requires that all contaminated ground water be restored to the water quality levels established under 40 CFR Parts 264.92-264.94 as modified by Part 192.02(a)(3)(i) and (ii). These levels are either background concentrations, the levels specified in Tables 1 and A, or alternate concentration limits.

Table 4-1 (continued). ARARs for Ground Water Environmental Surveillance

Standard, Requirement, Criterion, or Limitation	Citation	Description
EPA Standards for Inactive Uranium Mill Tailings Sites (continued)	40 CFR Part 192 as amended by 52 Fed. Reg. 36000 (Sept. 24, 1987)	4. The hydrologic and geologic assessment to be conducted at each site shall include a monitoring program sufficient to establish background ground-water quality through one or more upgradient wells (Part 192.20(a)(2)).
<u>ARAR Specific to the GJPO/GJPORAP</u>		
The Basic Standards For Groundwater (CO)	Colorado Dept. of Health, Water Quality Control Commission (5 CCR 1002-8)	Establishes statewide standards and a system for classifying ground water and adopting water quality standards for such classifications to protect existing and potential beneficial uses of ground waters.
<u>ARARs Specific to the MMTS</u>		
Definitions for Water Pollution Rules and General Requirements	Title 26, Chapter 11, Utah Code Annotated (R448-1, U.A.C.)	The statute and rules set forth the definitions and general requirements for the Utah Ground Water Quality Standards.
Ground Water Quality Standards (UT)	Title 26, Chapter 11, Utah Code Annotated (R448-6, U.A.C.)	Establishes a ground water classification system and ground water quality standards for all ground waters within the State of Utah.

organic carbon, pH, and specific conductance, in an effort to detect possible contamination problems. In 1979, the extent of contamination was unknown.

During the next 5 years, 56 wells were completed in the alluvium to determine background conditions and to characterize the contaminant plume. Higher-than-background concentrations of several constituents, including uranium, arsenic, selenium, molybdenum, and nitrate were measured in samples from the on-site wells. Pump tests were performed to estimate aquifer characteristics and determine the quantity of water affected by the leached products. Ground water quality was sampled semiannually for many chemical constituents, while water levels were monitored on a variable schedule, from biweekly to monthly.

In 1984, an intensive ground water quality sampling program was initiated. Organic compounds, heavy metals, and radiological constituents were analyzed for and their values compared with the UMTRCA ground water standards established in 40 CFR Part 192. Through this analysis, the determination was made that concentrations of arsenic, barium, radium, selenium, gross alpha, chromium, and lead in ground water samples exceeded federal standards. Results of the organic analyses indicated that six wells contained organic compounds in concentrations significantly higher than those in the background wells, but the validity of the results was questionable. Between 1984 and 1986, water levels were measured on a weekly basis as part of a ground water model verification exercise.

Semiannual ground water quality sampling was resumed in 1987 for a more limited list of constituents. At this time, water quality analyses focused on known contaminants for which standards existed or were proposed.

An organic characterization of alluvial ground water was conducted in 1991 and 1992 to follow up on the positive organic analytical results from 1984. Results of the 1991/92 quarterly sampling for Target Compound List volatiles, semivolatiles, herbicides, and pesticides determined that the alluvial aquifer was not contaminated with organic compounds.

A list of the ground water quality constituents analyzed for during the 13-year period from 1979 to 1992 is presented in Table 4-2.

More information concerning the annual ground water monitoring programs and results is in the Environmental Monitoring Reports for calendar years 1979 through 1991 (Bendix 1980; Korte and Thul 1981, 1982, 1983, 1984; Korte and Wagner 1985, 1986; Sewell and Spencer 1987; UNC Geotech 1988b, 1989c, 1990d; Chem-Nuclear Geotech, Inc. 1991c, 1992g).

Table 4-2. Water Quality Constituents Analyzed in Ground Water Samples at the GJPO/GJPORAP from 1979 to Present.

Nonradiological Constituents: Inorganic	Nonradiological Constituents: Organic	Radiological Constituents
Alkalinity	Endrin	Gross Alpha
Aluminum	Lindane	Gross Beta
Ammonium-Nitrogen	Methoxychlor	Radium-226
Arsenic	Total Organic Carbon	Radium-228
Barium	Total Organic Halogen	Thorium-230
Beryllium	Total Phenolics	Thorium-232
Cadmium	Toxaphene	Uranium-234
Calcium	2,4-D	Uranium-238
Chloride	2,4,5-TP (Silvex)	
Chromium	TCL[a] Volatiles	
Copper	TCL Semivolatiles	
Dissolved Oxygen	TCL Pesticides/PCBs	
Fecal Coliform	TCL Herbicides	
Fluoride		
Iron		
Lead		
Magnesium		
Manganese		
Mercury		
Molybdenum		
Nickel		
Nitrate-Nitrogen		
Nitrite-Nitrogen		
pH		
Phosphate		
Potassium		
Selenium		
Silver		
Specific Conductance		
Sulphate		
Total Dissolved Solids		
Uranium		
Vanadium		
Zinc		

[a]TCL = Target Compound List

4.2.2.2 Planned Ground Water Monitoring

4.2.2.2.1 *Monitoring Objectives*

The objectives of the ground water monitoring program for the GJPO/GJPORAP are

1. to determine the baseline water quality and quantity conditions of the shallow alluvial aquifer underlying the site;

2. to characterize the type and extent of the contamination plume within the aquifer;

3. to verify compliance with federal and state ground water quality standards; and

4. to detect changes in water quality resulting from remedial action.

Historical ground water monitoring programs have accomplished the first two monitoring objectives (see Section 4.2.2.1). The goals of the current and future ground water monitoring program will be to continue to measure water quality constituents for compliance and to detect changes resulting from remedial action. Monitoring will continue for the GJPO/GJPORAP until the contaminated ground water is restored to levels that comply with ground water quality standards.

Ground water quality at the GJPO Facility must comply with both federal and state standards as mandated by UMTRCA of 1978 and the Colorado Water Quality Control Act (CRS 25-8-101 to 612). The numeric standards applicable to the site are listed in 40 CFR Part 192.32 and in the Colorado Department of Health, Water Quality Control Division publication, *The Basic Standards for Ground Water*. These standards are listed in Tables 4-3 and 4-4.

All of the constituents listed under 40 CFR 192.32 were measured during the mid-1980s; of these, arsenic, barium, chromium, lead, molybdenum, nitrate, selenium, uranium, radium, and gross alpha concentrations in ground water samples exceeded their respective standards. Although standards were not exceeded by cadmium, it was found in higher-than-background concentrations.

Historical monitoring showed that the state standards for radium and total dissolved solids were regularly exceeded.

Present and future monitoring for the GJPO/GJPORAP will focus on constituents that do not presently meet federal and state standards and on constituents associated with uranium mill tailings contamination for which no standards exist. Specific conductance, pH, and alkalinity will be measured in the field to detect gross changes in water quality. Table 4-5 lists the analytes to be measured in samples from the GJPO/GJPORAP, along with their respective reporting limits.

Table 4-3. Federal Standards for Ground Water (40 CFR Part 192.32)

Constituent	Maximum Concentration
Arsenic	0.05 mg/L
Barium	1.0 mg/L
Cadmium	0.01 mg/L
Chromium	0.05 mg/L
Lead	0.05 mg/L
Mercury	0.002 mg/L
Selenium	0.01 mg/L
Silver	0.05 mg/L
Endrin	0.0002 mg/L
Lindane	0.004 mg/L
Methoxychlor	0.1 mg/L
Toxaphene	0.005 mg/L
2,4-D	0.1 mg/L
2,4,5-TP Silvex	0.01 mg/L
Radium-226	20 pCi/L[a]
Radium-228	20 pCi/L[a]
Gross Alpha (excluding radon and uranium)	15 pCi/L
Uranium 234+238	30 pCi/L[a]
Molybdenum	0.1 mg/L
Nitrate (as N)	10 mg/L

[a]Proposed maximum concentration from *Federal Register* July 18, 1991, (40 CFR Parts 141 and 142).

Table 4-4. State of Colorado Standards for Ground Water Quality[a]

Constituent	Maximum Concentration
Total Dissolved Solids	1.25 times the background value
Radiological	pCi/L
Cesium-134	80
Plutonium-238+239+240	15
Radium-226+228	5
Strontium-90	8
Thorium-230+232	60
Tritium	20,000
Carcinogenic Organics	μg/L
Aldrin	0.1
Benzene	5
Benzidine	50
Carbon Tetrachloride	5
Chlordane	0.1
Chloroethyl Ether (BIS-2)	10
DDT	0.1
Dichloroethane 1,2	5
Dichloropropane 1,2	6
Dieldrin	0.1
Dioxins	0.01
2,3,7,8-Tetrachlorodibenzo-p-dioxin	3
Diphenylhydrazine 1,2	20
Ethylene Dibromide	10
Heptachlor	0.1
Heptachlor Epoxide	0.1
Hexachlorobenzene	10
Hexachlorocyclohexane (Lindane)	4
Polychlorinated Biphenyls (PCBs)	0.5
Toxaphene	5
Trichloroethylene	5
Trichlorophenol 2,4,6	10
Trihalomethanes (total)	100
Vinyl Chloride	2

[a]Ground Water at the GJPO is classified as Class 4--"Potentially Usable Quality."

Table 4-4 (continued). State of Colorado Standards for Ground Water Quality

Constituent	Maximum Concentration
<u>Non-Carcinogenic Organics</u>	<u>µg/L</u>
Aldicarb	10
Carbofuran	36
Chlorobenzene	300
Dichlorobenzene 1,2	620
Dichlorobenzene 1,3	620
Dichlorobenzene 1,4	75
Dichloroethylene 1,1	7
Dichloroethylene 1,2-Cis	70
Dichloroethylene 1,2-Trans	70
Dichlorophenol 2,4	21
Dichlorophenoxyacetic Acid (2,4-D)	100
Endrin	0.2
Ethylbenzene	680
Ethylene Glycol	7,000
Hexachlorobutadiene	14
Hexachlorocyclopentadiene	49
Isophorone	1,050
Methoxychlor	100
Nitrobenzene	10
Pentachlorobenzene	10
Pentachlorophenol	200
Tetrachlorobenzene 1,2,4,5	10
Tetrachloroethylene	10
Toluene	2,420
Trichloroethane 1,1,1	200
Trichloroethane 1,1,2	28
Trichlorophenol 2,4,5	700
Trichlorophenoxypropionic Acid (2,4,5-TP)	10

Table 4-5. Ground Water Quality Analytes and Respective Reporting Limits, GJPO/GJPORAP

Nonradiological Constituent	Reporting Limit	Radiological Constituent	Reporting Limit
Arsenic	0.010 mg/L	Gross alpha (excluding radon and uranium)	2.0 pCi/L
Barium	0.20 mg/L	Radium-226	0.5 pCi/L
Cadmium	0.003 mg/L	Radium-228	1.0 pCi/L
Calcium	5.0 mg/L	Uranium-234	0.5 pCi/L
Chloride	0.10 mg/L	Uranium-238	0.5 pCi/L
Chromium	0.010 mg/L	Thorium-230	1.0 pCi/L
Iron	0.10 mg/L	Thorium-232	1.0 pCi/L
Lead	0.003 mg/L		
Magnesium	5.0 mg/L		
Manganese	0.015 mg/L		
Molybdenum	0.050 mg/L		
Nitrate	0.01 mg/L		
Potassium	5.0 mg/L		
Selenium	0.005 mg/L		
Sodium	5.0 mg/L		
Sulfate	0.10 mg/L		
Total Dissolved Solids	10 mg/L		
Vanadium	0.050 mg/L		
Alkalinity	None Def.		
pH	0.1 Unit		
Specific Conductance	None Def.		
Total Organic Carbon	0.10 mg/L		

Concentrations of selected constituents in ground water samples from Table 4-5 will be compared over time to detect changes in water quality caused by remedial action. These constituents may include arsenic, barium, chromium, lead, molybdenum, nitrate, selenium, uranium, radium, and gross alpha. Mill tailings removal began in 1990 and will continue through 1993; improvement in ground water quality is expected to occur after completion of remedial action.

4.2.2.2.2 *Sampling Plan*

Thirteen wells completed in the alluvial aquifer will be sampled quarterly (March, June, September, and December) for the ground water quality constituents listed in Table 4-5 (see Figure 4-1 for locations). Quarterly sampling will allow seasonal fluctuations in the chemical concentrations to be examined and will reduce the problem of serial correlation if the data are statistically analyzed. Because water levels are known to vary considerably in response to the seasons and to storm events, water levels will be measured monthly. Two of the wells, GJ84-9 and GJ84-10, are located upgradient from the mill tailings contamination plume and will provide background water quality data. The remaining 11 wells are completed in contaminated/previously contaminated areas of the aquifer along the perimeter of the Facility and will represent on-site and downgradient conditions. All wells will be visually inspected monthly for damage. Table 4-6 lists the monitoring wells that will be sampled.

Table 4-6. Ground Water Sampling Wells, GJPO/GJPORAP[a]

Well No.	Representative of	Total Depth (ft)
GJ84-09	Upgradient	31.5
GJ84-10	Upgradient	72.0
1-9SA	On Site	32.0
8-4S	On Site	10.0
11-1S	On Site	30.0
14-6NA	On Site	30.0
10-19N	On Site	28.0
13-16NA	On Site	19.1
14-13NA	On Site	20.4
GJ87-15	On Site	19.0
11-12NA	On Site	18.0
5-12NA	Downgradient	28.0
GJ84-04	Downgradient	23.0

[a]All well completions are in the alluvial aquifer.

General procedures for sampling ground water quality and measuring water levels are outlined in the *Environmental Procedures Catalog*, [Procedures GN-3(P), 6(P), 7(P), 8(P), 9(P), 13(P) and LQ-1(G), 2(T), 3(P), 4(T), 5(T), 7(T), 8(T), 10(P), 11(P), 12(P), 18(P)] (Chem-Nuclear Geotech, Inc. 1992j), which incorporates the standard procedures published by the EPA (US-EPA 1985, 1987b), and DOE (US-DOE 1987) for ground water sampling. Specific procedures will be described in the *Sampling and Analysis Plan for Environmental Monitoring* (Chem-Nuclear Geotech, Inc. 1992a). All monitoring wells

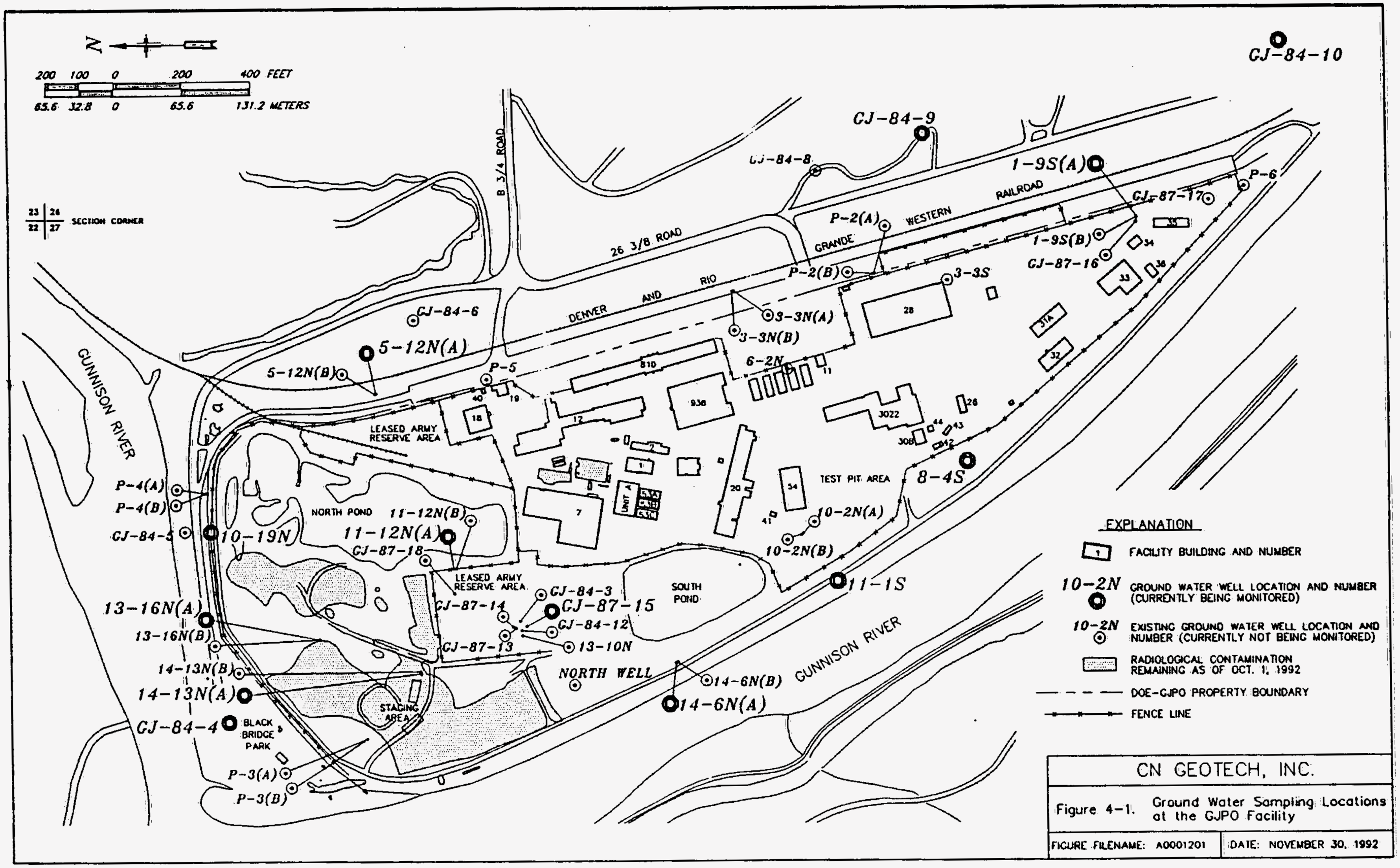

Figure 4-1. Ground Water Sampling Locations at the GJPO Facility

will be permitted, constructed, and/or abandoned according to Colorado Division of Water Resources requirements (State of Colorado 1988).

Ground water samples will be analyzed by the Geotech Analytical Chemistry Laboratory or by a subcontracted qualified laboratory. Analytical procedures followed by the Geotech Analytical Chemistry Laboratory will be those outlined in the *Analytical Chemistry Laboratory Handbook of Analytical and Sample Preparation Methods* (Chem-Nuclear Geotech, Inc. 1992e). Subcontracted laboratories will adhere to the analytical methods and detection limits prescribed by the EPA (US-EPA 1986) for evaluating solid wastes. To ensure the integrity of the samples from collection in the field to the time of laboratory analysis, a chain-of-custody record will be maintained for each possession transfer.

QA and QC measures will be implemented during all sampling and analysis activities. The precision and accuracy of the sample results will be determined by use of field and laboratory QC measures. Field QC will be accomplished by the analysis of field duplicates (one sample per batch or 5 percent) and equipment blanks (one sample per trip for each piece of nondedicated equipment used). Laboratory QC will be accomplished by the analysis of blind duplicates, spikes, spike duplicates, method blanks, and calibration standards when applicable to the analytical method being performed at a frequency in accordance with the *Analytical Chemistry Laboratory Administrative Plan and Quality Control Methods* (Chem-Nuclear Geotech, Inc. 1992f). Details of the QA program are provided in Section 8.0 and Appendix A of this document.

4.2.2.2.3 *Data Management*

The Data Manager, appointed by the Geotech Project Manager, will maintain a data base for all the ground water monitoring data. Data management will include (1) receiving laboratory results via computer network, (2) entering information into the appropriate data base, and (3) formatting the data for report preparation. Data will be stored in an ORACLE data base package on a MicroVAX computer system and will be backed up weekly. All documentation will be centralized in a permanent project file in Geotech's Records Management Section.

4.2.2.2.4 *Data Analysis/Reporting Format*

Data will be analyzed and reported the same as surface water monitoring data. Procedures for data analyses and reporting, including statistical methodology, are described in Section 3.2.2.2.4, Data Analysis/Reporting Format. Table 4-5 lists the analytes that will be compared with the established standards presented in Tables 4-3 and 4-4.

4.2.2.3 Responsible Organizations

It is the responsibility of the DOE-GJPO Manager to direct the ground water monitoring effort. The Geotech Program Manager directs the Geotech Project Manager to implement the ground water monitoring program. Currently, this responsibility resides with the Environmental Services Section. The Geotech Project Manager will be responsible for planning and budgeting ground water projects, monitoring ground water project activities, conducting data evaluation, and preparing reports. To accomplish these tasks, the Project Manager will assign ground water projects to personnel within Geotech who possess the technical expertise to perform the required activities, or the work will be subcontracted to outside organizations. (An organization chart is provided in Appendix A).

4.2.3 <u>MMTS</u>

Ground water monitoring at the Monticello Millsite has focused on the underlying alluvial aquifer, which is contaminated by the leached products of uranium mill tailings. The aquifer comprises a heterogeneous mixture of gravel, sand, silt, and minor amounts of clay, averaging about 4.5 meters (15 feet) thick. Hydraulic conductivities measured in the alluvium vary from 0.003 to 6 meters (0.01 foot to 20 feet) per day. While recharge of the aquifer is from infiltration of precipitation and surface water, discharge is into the local surface waters of Montezuma Creek. Ground water flow directions generally are to the east and southeast. The average saturated thickness of the aquifer is 3 meters (10 feet).

Underlying the alluvium, and separating it from a deeper aquifer, are the impermeable siltstones and shales of the Mancos Shale and Dakota Sandstone Formations. These units limit the potential for percolation of alluvial water into the underlying aquifer of the Burro Canyon Formation, which is used for domestic water supply. There is no evidence from ground water well samples that the Burro Canyon aquifer is being degraded by the tailings piles.

Descriptions of the hydrogeologic setting and extent of the contaminant plume are available in several documents, including the *GJPO Ground Water Protection Management Plan* (UNC Geotech 1990e) and the *Final Remedial Investigation/Feasibility Study--Environmental Assessment for the Monticello, Utah, Uranium Mill Tailings Site* (UNC Geotech 1990c).

4.2.3.1 Historical Ground Water Monitoring

Ground water quality monitoring began in 1980 to determine if contamination problems existed at the Monticello Millsite. Five wells were completed in the alluvial aquifer. During the months of April, August and December, ground water samples were analyzed for a number of water quality constituents, including radiological constituents, heavy metals, and inorganic ions. Sampling of only these wells continued semiannually until

50 additional wells were drilled in 1982 and 1983. The new wells allowed comparisons to be made between background water quality and on-site and downgradient water quality. Within the on-site and downgradient wells, samples were determined to be contaminated by uranium, molybdenum, vanadium, and selenium.

In 1984 and 1985, bail tests and pump tests were performed on wells completed in the alluvial and Burro Canyon aquifers to estimate their hydraulic properties. Sampling frequencies for water levels and ground water quality also were intensified to characterize the contaminant plume.

In 1987, semiannual ground water quality sampling was resumed at 13 wells located upgradient, on, and downgradient of the site. Water levels were measured quarterly in these wells. Twelve wells were drilled in the fall of 1992 to develop a baseline characterization of upgradient and downgradient water quality conditions in the alluvial and Burro Canyon aquifers and Dakota Sandstone Formation. During fiscal year 1993, these and other selected wells will be sampled four times. Figures 4-2 and 4-3 show the locations of all wells to be monitored during fiscal year 1993.

Since 1979, more than 40 chemical parameters have been investigated. These are the same parameters investigated in samples from the GJPO/GJPORAP and are listed in Section 4.2.2.1, Table 4-2. More complete descriptions of the yearly monitoring programs and results are contained in the Environmental Monitoring Reports for calendar years 1979 through 1991 (Bendix 1980; Korte and Thul 1981, 1982, 1983, 1984; Korte and Wagner 1985, 1986; Sewell and Spencer 1987; UNC Geotech 1988a, 1989b, 1990b; Chem-Nuclear Geotech, Inc. 1991b, 1992d).

4.2.3.2 Planned Ground Water Monitoring

4.2.3.2.1 *Monitoring Objectives*

The objectives of the ground water monitoring program for the MMTS are:

1. to determine the baseline water quality and quantity conditions of the Burro Canyon and shallow alluvial aquifers underlying the site;

2. to characterize the type and extent of the contamination plume within the alluvial aquifer (and Dakota Sandstone Formation, if affected);

3. to verify compliance with federal and state ground water quality standards; and

4. to detect changes in water quality resulting from remedial action.

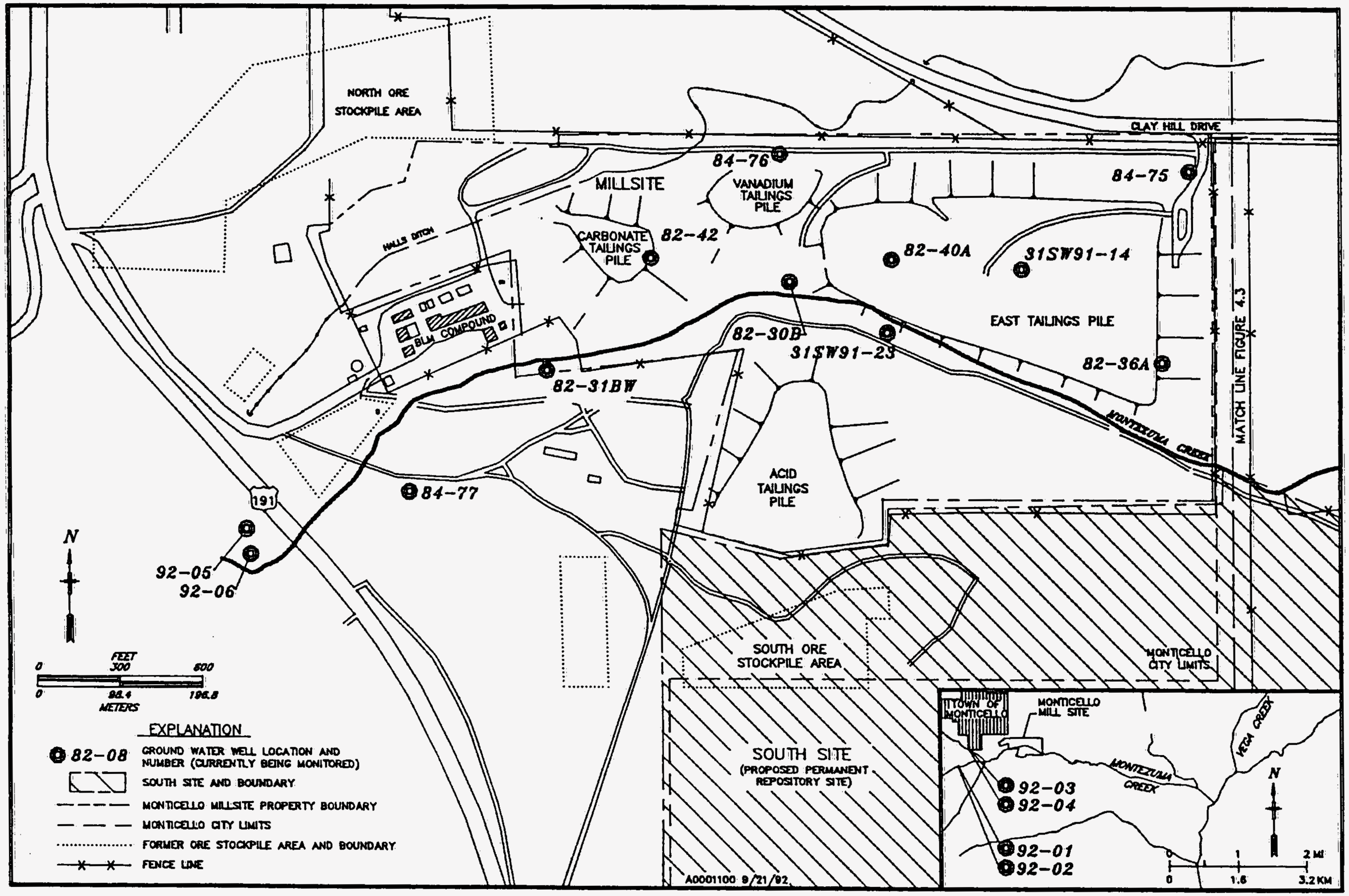

Figure 4-2. Ground Water Sampling Locations On Site and Upgradient of the Monticello Millsite

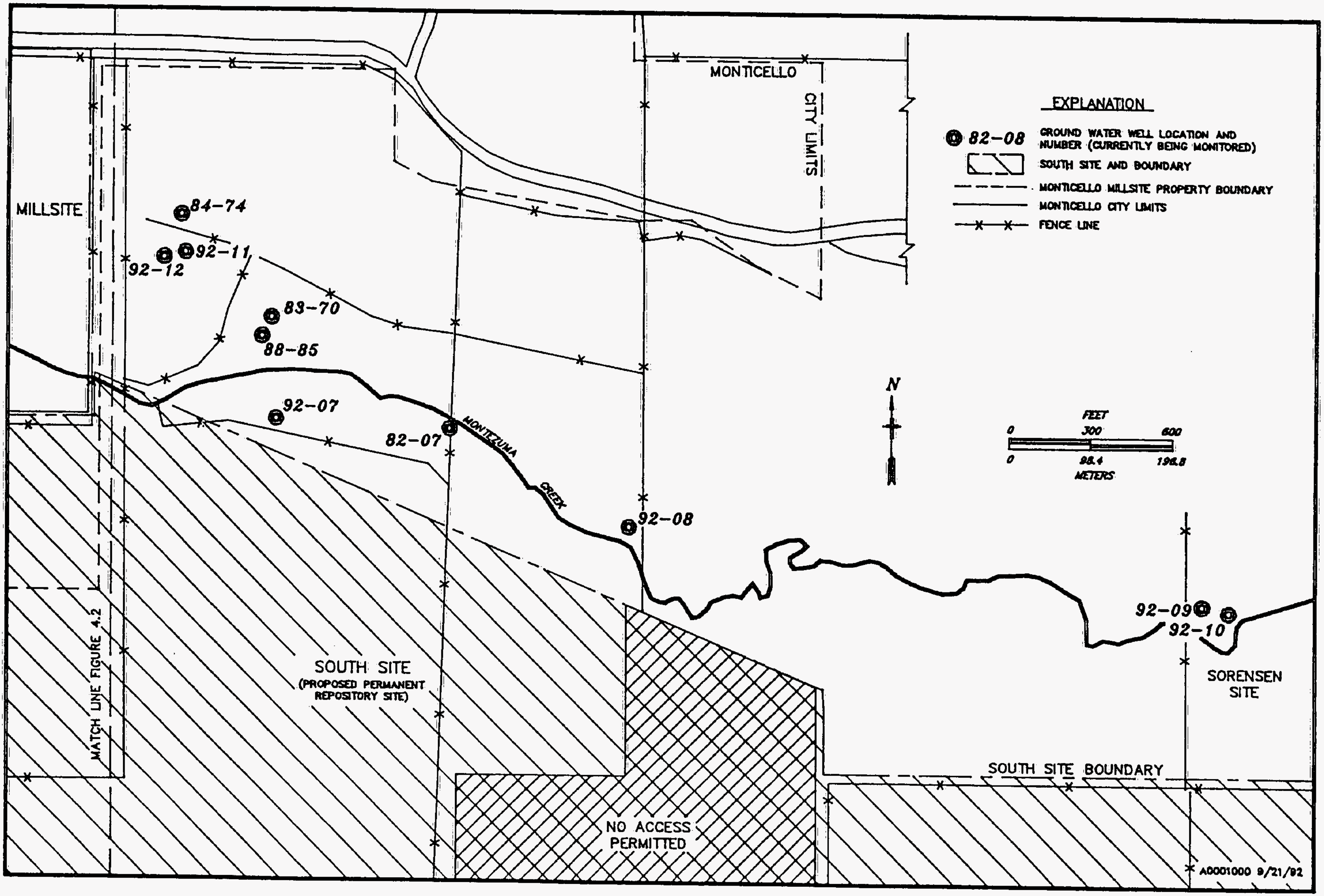

Figure 4-3. Ground Water Sampling Locations Downgradient of the Monticello Millsite

4.2.3.2.2. *Sampling Plan*

Twenty-six wells will be sampled four times during fiscal year 1993, after which a new sampling schedule will be established. Table 4-7 lists the ground water quality constituents that will be sampled for in all upgradient and on-site wells and in downgradient alluvial wells. With the exception of organic compounds, downgradient Burro Canyon and Dakota Sandstone wells will be sampled for the same constituents.

Table 4-7. Ground Water Quality Analytes, MMTS

Analytical Parameters	Analytes
Volatile Organic Compounds	Target Compound List[a]
Semivolatile Organic Compounds	Target Compound List[a]
Pesticides/PCBs	Aldrin Alpha-BHC Beta-BHC Delta-BHC Gamma-BHC (lindane) Alpha-Chlordane Gamma-Chlordane 4,4'-DDD 4,4'-DDE 4,4'-DDT Dieldrin Endosulfan I Endosulfan II Endosulfan Sulfate Endrin Endrin Aldehyde Heptachlor Heptachlor Epoxide Methoxychlor Toxaphene

[a]Target Compound List volatiles and semivolatiles are listed in the *Monticello Mill Tailings Site, Operable Unit III, Surface- and Ground- Water Remedial Investigation/ Feasibility Study Field Sampling Plan* (Chem-Nuclear Geotech, Inc. 1992c).

Table 4-7 (continued). Ground Water Quality Analytes, MMTS

Analytical Parameters	Analytes
Pesticides/PCBs	Aroclor 1016 Aroclor 1221 Aroclor 1232 Aroclor 1242 Aroclor 1248 Aroclor 1254 Aroclor 1260
Herbicides	2,4-D 2,4-DB 2,4,5-T 2,4,5-TP (Silvex) Dalapon Dichloroprop
Major Anions	Chloride Fluoride Nitrate Nitrite Nitrate and Nitrite Sulfate
Major Cations	Ammonium Calcium Magnesium Potassium Sodium
Metals	Aluminum Antimony Arsenic Barium Beryllium Boron Cadmium Chromium Copper Cyanide Iron Lead

Table 4-7 (continued). Ground Water Quality Analytes, MMTS

Analytical Parameters	Analytes
Metals	Manganese Mercury Molybdenum Nickel Selenium Silver Strontium Thallium Vanadium Zinc
Total Dissolved Solids	TDS
Radionuclides	Gross Alpha Gross Beta Lead-210 Polonium-210 Radium-226 Radium-228 Thorium-230 Thorium-232 Uranium-234 Uranium-238 Radon-222

Depending on the results of the first-round sampling, samples from downgradient Burro Canyon and Dakota Sandstone wells from later rounds may be investigated for organic compounds. Table 4-8 lists the wells to be sampled, and Figures 4-2 and 4-3 show the locations of the wells. Of the 26 wells to be sampled, 16 are completed in the alluvial aquifer, one is completed in the Dakota Sandstone Formation, and 9 are completed in the Burro Canyon aquifer. Water level measurements and monitoring well inspections will be conducted monthly.

Sampling and laboratory analysis procedures, QA and QC measures, and reporting limits for analytical parameters are described in the *Monticello Mill Tailings Site, Operable Unit III, Surface and Ground-Water Remedial Investigation/Feasibility Study Field Sampling Plan* (Chem-Nuclear Geotech, Inc. 1992c) and *Quality Assurance Project Plan* (Chem-Nuclear Geotech, Inc. 1992i).

Table 4-8. Wells for Ground Water Sampling, MMTS

Well No.	Aquifer	Representative of
92-01	Alluvium	Upgradient
92-02	Burro Canyon	Upgradient
92-03	Alluvium	Upgradient
92-04	Burro Canyon	Upgradient
92-05	Alluvium	Upgradient
92-06	Burro Canyon	Upgradient
82-30B	Alluvium	On Site
82-36A	Alluvium	On Site
82-40A	Alluvium	On Site
82-42	Alluvium	On Site
82-31B-W	Alluvium	On Site
31SW91-14	Alluvium	On Site
31SW91-23	Alluvium	On Site
84-75	Burro Canyon	On Site
84-76	Burro Canyon	On Site
84-77	Burro Canyon	On Site
82-07	Alluvium	Downgradient
83-70	Burro Canyon	Downgradient
84-74	Burro Canyon	Downgradient
88-85	Alluvium	Downgradient
92-07	Alluvium	Downgradient
92-08	Alluvium	Downgradient
92-09	Alluvium	Downgradient
92-10	Burro Canyon	Downgradient
92-11	Alluvium	Downgradient
92-12	Dakota Sandstone	Downgradient

4.2.3.2.3 *Data Management*

Data storage and management will be the same as that described for the GJPO/GJPORAP (Section 4.2.2.2.3).

4.2.3.2.4 *Date Analysis/Reporting Format*

Data analysis techniques and reporting formats will be the same as those described for the GJPO/GJPORAP (Section 4.2.2.2.4).

4.2.3.3 Responsible Organizations

Responsible organizations will be the same as those described for the GJPO/GJPORAP (Section 4.2.2.3).

5.0 Air

5.0 AIR

5.1 EFFLUENT MONITORING

5.1.1 Regulatory Requirements

Air effluent monitoring for the GJPO/GJPORAP is conducted to verify compliance with local, state, and federal regulatory requirements outlined in Table 5-1. No air effluent monitoring is conducted for the MMTS at this time (see Section 5.1.3).

5.1.2 GJPO/GJPORAP

Sources of radiological emissions from the GJPO/GJPORAP include the uranium mill tailings piles, Sample Preparation Facility Baghouse (Baghouse), Radon Laboratory, calibration test pits, Analytical Chemistry Laboratory, and ORNL Sample Preparation Facility. Air effluent from these sources is monitored with high-volume ambient air particulate samplers and environmental radon monitors. The only point source monitored is the Baghouse stack (Figure 5-1). Although the ORNL Sample Preparation Facility exhausts unfiltered air through a stack, EPA, Region VIII, has excluded this source from the stack sampling requirements of 40 CFR Part 61, Subpart H. An exclusion was granted because of the low levels of radioactivity associated with and small amount of material the Facility processes. EPA requires emissions from the Facility to be estimated annually using the method described in 40 CFR Part 61, Appendix D, and that they be included in the GJPO Facility source term.

Nonradiological emission sources from the GJPO/GJPORAP include the Analytical Chemistry Laboratory, Boiler Plant, Petrology Laboratory, and uranium mill tailings piles (particulate matter). Air emission permits from the Colorado Department of Health, Air Pollution Control Division, have been obtained for the first three sources, and as a condition of the permits, the sources are monitored for opacity. Additionally, the permit obtained for the Analytical Chemistry Laboratory establishes limits on the quantity of chemicals the laboratory may use annually. To ensure permit compliance, an inventory of hazardous/radioactive chemicals is maintained by the laboratory and updated annually.

Annual emissions from the Boiler Plant are estimated by multiplying the emission factor by the annual volume of natural gas consumed. On the basis of this calculation, the individual emission rate for each pollutant emitted from the boiler does not exceed the limits under the Colorado Air Pollution Control Regulations. Therefore, the current permit does not require air pollution devices, but does establish limits on the amount of gas consumed annually.

The pollutant of concern emitted from the Petrology Laboratory is asbestos fibers from the analysis of building materials containing asbestos and from the counting of asbestos fibers on lapel air monitoring filters. Both analyses are performed under hoods equipped with HEPA filters having an efficiency rating of 99.97 percent for particles

Table 5-1. ARARs for Air Effluent Monitoring

Standard, Requirement, Criterion, or Limitation	Citation	Description
ARARs Specific to the GJPO/GJPORAP		
General Environmental Protection Program	DOE 5400.1 Chapter IV Part 6	Requirements for the environmental monitoring of radioactive materials are in DOE Orders in the 5400 series dealing with radiation protection of the public and the environment. Airborne radiation and radioactive materials discharged from DOE facilities shall comply with the requirements of 40 CFR Part 61, "National Emission Standards for Hazardous Air Pollutants." An assessment of the potential radiation dose to members of the public that could have resulted from site operations shall be made for facilities required to conduct effluent and environmental radiological monitoring. Assessments shall be made in accordance with the requirements of DOE orders in the 5400 series dealing with radiation protection of the public and environment.
Radiation Protection of the Environment	DOE 5400.5 Chapter I Part 8a Chapter II Part 1a(1)	Demonstrations of compliance with the Public and the requirements of this order generally will be calculations that make use of information obtained from monitoring and surveillance programs. The ability to detect, quantify, and adequately respond to unplanned releases of radioactive material to the environment relies on in-place effluent monitoring of environmental transport and diffusion conditions and of assessment capabilities.

Table 5-1 (continued). **ARARs for Air Effluent Monitoring**

Standard, Requirement, Criterion, or Limitation	Citation	Description
Radiation Protection of the Public and the Environment	DOE 5400.5 Chapter I Part 8a Chapter II Part 1a(1)	The exposure of members of the public to radiation sources as a consequence of all routine DOE activities shall not cause an effective dose equivalent of greater than 100 mrem.
Radiological Effluent Monitoring and Environmental Surveillance	DOE Environmental Regulatory Guide Chapter 3.0	All airborne emissions from DOE-controlled facilities shall be evaluated and their potential for release of radionuclides assessed. The potential for emissions shall include consideration of the loss of emission control while otherwise operating normally. The results of this evaluation also provide the basis for the site's effluent monitoring program, which shall be documented in the site Environmental Monitoring Plan to show 1. Effluent monitoring extraction locations used for providing quantitative emission data for each emission point. 2. Procedures and equipment needed to perform the extraction and measurement. 3. Frequency and analysis required for each extraction. 4. Minimum detection level accuracy. 5. Quality assurance components. 6. Investigation and alarm levels.

Table 5-1 (continued). ARARs for Air Effluent Monitoring

Standard, Requirement, Criterion, or Limitation	Citation	Description
Radiological Effluent Monitoring and Environmental Surveillance (continued)	DOE Environmental Regulatory Guide Chapter 3.0	Airborne emissions from DOE-controlled facilities that have the potential for causing doses exceeding 0.1 mrem (effective dose equivalent) in a year shall be monitored in accordance with the requirements of DOE 5400.1 and DOE 5400.5. The monitoring effort should be commensurate with the importance of the sources during routine operation and from potential accidents with respect to their potential contribution to public dose or to contamination of the environment. Diffuse sources shall be identified and assessed for their potential to contribute to public dose and shall be considered in designing the site effluent monitoring and environmental surveillance program.
National Emission Standards for Hazardous Air Pollutants (NESHAPS)	40 CFR Part 61 Subpart H	Emissions of radionuclides to the ambient air from Department of Energy facilities shall not exceed those amounts that would cause any member of the public to receive in any year an effective dose equivalent of 10 mrem/yr excluding radon and its daughters. To determine compliance with the standard, radionuclide emission shall be determined and effective dose equivalent values to members of the public calculated using EPA-approved sampling procedures and computer models.

Table 5-1 (continued). ARARs for Air Effluent Monitoring

Standard, Requirement, Criterion, or Limitation	Citation	Description
National Emission Standards for Hazardous Air Pollutants (NESHAPS) (continued)	40 CFR Part 61 Subpart H	The owners or operators of each facility shall submit an annual report to both EPA headquarters and the appropriate regional office by June 30 that includes the results of the monitoring asrecorded in DOE's Effluent Information System and the dose calculations required by thisregulation.
Air Pollution Emission Notification	Colorado Air Quality Act, revised 1982	Emission of air pollutants from any facility is prohibited until an Air Pollution Emission Notification (APEN) has been filed with the Air Pollution Division of the Colorado Department of Health.
National Primary and Secondary Ambient Air Standards	40 CFR, Part 50	National primary ambient air quality standards define levels of air quality that the EPA judges Quality to be necessary to protect the public health. National secondary air quality standards define levels of air quality that the EPA judges to be necessary to protect the public welfare from any known or anticipated adverse effects of a pollutant.

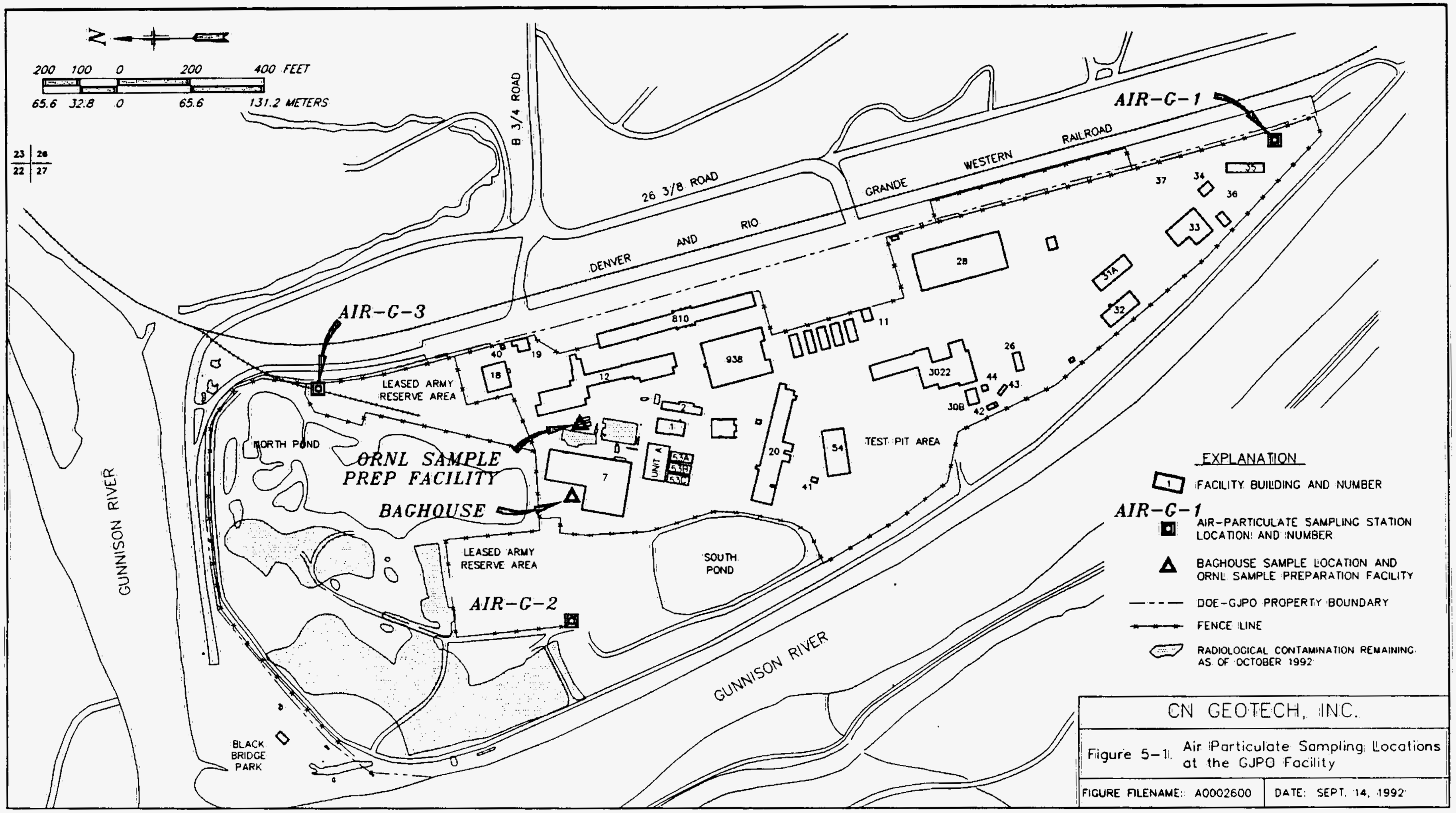

Figure 5-1. Air Particulate Sampling Locations at the GJPO Facility

0.3 micrometer (μm) or greater. The filters are replaced when the pressure differential across the filter reaches the manufacturer's recommended value. To ensure filter integrity and proper gasket sealing, filters are tested each time they are replaced, in accordance with procedures described in the *Nuclear Air Cleaning Handbook* (Burchsted and others 1979). With the HEPA filter installed, the air emissions permit requires only opacity monitoring of Petrology Laboratory emissions.

The fourth nonradiological emission from the GJPO/GJPORAP, particulate matter from the tailings piles, is monitored through the air particulate monitoring program (Section 5.1.2.2.2).

5.1.2.1 Historical Air Effluent Monitoring

The GJPO/GJPORAP air particulate sampling program was initiated in December of 1985. The objective of the air particulate sampling program during the pre-remedial phase was surveillance of the ambient air quality to comply with federal regulations and DOE orders. The initial air particulate sampling network consisted of three high-volume air particulate samplers mounted on 3.5-meter (11.5-foot) towers. Ambient air was sampled at 40 standard cubic feet per minute for 24 hours every sixth day. In 1987, each of the air particulate samplers was equipped with a 10-μm size-selective inlet, which allowed only particles of 10 μm or smaller to pass through and be sampled. During 1990, a fourth sampling station (AIR-G-7) was added southeast of the on-site tailings stockpile, and the sampling frequency at all the stations was increased from every sixth day to every third day. These changes were made in response to the increase in remedial activities of the GJPORAP and to monitor airborne particulates from tailings areas. The sampling sites were selected on the basis of wind-rose data for the GJPO Facility. Air sample filters were analyzed for radium-226, thorium-230, uranium, lead, and PM_{10} particulate matter (less than 10 μm in diameter). Concentrations of air particulates never exceeded the standards established by 40 CFR Part 50 and DOE Order 5400.5 (see Section 5.1.2.2.1 for standards).

In January 1992, the air particulate monitoring strategy was revised again. Because the 24-hour sampling period required for PM_{10} sampling was not long enough to allow radioparticulate accumulations to reach measurable levels, radioparticulate sampling was begun on a separate schedule. Samplers were run continuously for a 5-day period each month for the purpose of radioparticulate sampling only. The frequency of PM_{10} sampling was returned to once every sixth day (for a 24-hour period). Lead was removed from the analyte list because measured levels of this particulate were consistently two orders of magnitude below established standards. Additionally, Station AIR-G-7 was removed because the majority of on-site remedial activity had been completed.

Environmental radon monitoring began at the GJPO Facility and surrounding areas in 1985 with the establishment of 25 atmospheric radon sample locations. After the initial radon characterization effort was completed, and because no remedial activities were occurring at the Facility, the number of sample locations was reduced from 25 to 8 in

1986. In November of 1990, the number of sample locations was increased to 13 (7 on-site and 6 off-site locations) in response to GJPORAP activities. From 1985 to 1990, atmospheric radon concentration was measured nominally at 1 meter above-ground level with Terradex Track Etch, Type F, alpha-sensitive detectors. During the first quarter of 1991, Landauer, RadTrak radon detectors were installed and used in place of the Terradex Track Etch brand. Detectors have been collected and analyzed quarterly (3-month exposure) since inception of the program. Historic atmospheric radon concentrations have never exceeded the guidance established by DOE Order 5400.5 (3×10^{-9} microcuries per milliter [μCi/mL]).

Sampling of the effluent from the Baghouse has been included in the air effluent monitoring program for the GJPO Facility. The Baghouse is the air cleaning device for the Sample Preparation Facility. The Sample Preparation Facility exhausts particulates from sample preparation activities through a vent system that converges to a duct having a series of bags that filter the particulates. The data generated from the sampling of the Baghouse are used to demonstrate compliance with the dose limits set forth in 40 CFR Part 61, Subpart H (NESHAPS) and DOE Order 5400.5.

Sampling of the Baghouse effluent stream was originally performed in October 1989 to satisfy Subpart H requirements and to characterize emissions. The data collected were later invalidated because of improper sampling procedures. Baghouse monitoring was not performed after this initial characterization because of delays in Baghouse remodeling and installation of the emission monitoring port. To perform the necessary dose calculations, Baghouse emission values were estimated for 1990 and 1991 using the method described in Appendix D of 40 CFR Part 61. Radionuclide data obtained from the Baghouse emission estimates were converted to source strengths and used in the AIRDOS-PC computer model to determine the effective dose equivalent. Results from the modeling runs estimated an effective dose equivalent to the maximally exposed individual of 6.0×10^{-4} mrem/year. The EPA standard for dose caused by airborne emissions is 10 mrem/year. In August 1992, an emission monitoring port was installed in the Baghouse, and sampling on a continuous basis was begun.

Opacity monitoring of the Analytical Chemistry Laboratory, Boiler Plant, Petrology Laboratory, and Baghouse was begun in November 1991. Results of monthly monitoring have shown that emissions from these sources have complied with requirements of air emission permits.

5.1.2.2 Planned Air Effluent Monitoring

5.1.2.2.1 *Monitoring Objectives*

The objectives of the air effluent monitoring program for the GJPO/GJPORAP are

1. to establish a baseline of air quality conditions that exist at the GJPO; and

2. to verify compliance with federal ambient air quality standards, federal radiation protection standards, state air emission permit requirements, and DOE orders regulating radiation protection of the public.

Historical air effluent monitoring has accomplished both monitoring objectives; the objective of current and future air effluent monitoring programs will be to continue to evaluate compliance.

National primary and secondary ambient air quality standards are established under Section 109 of the Clean Air Act. The standard for PM_{10} particulate matter specifies an annual average of not more than 50 micrograms per cubic meter ($\mu g/m^3$) and a 24-hour maximum concentration not to exceed 150 $\mu g/m^3$. The ambient air quality standard for lead specifies that the concentration of lead must not exceed 1.5 $\mu g/m^3$ averaged for a calendar quarter. Lead concentrations in ambient air are no longer measured at the GJPO because historical measurements were consistently two orders of magnitude below the standard.

In 40 CFR Part 61, Subpart H, emission standards are set for radionuclides other than radon from DOE facilities. Emissions of these radionuclides to the ambient air from DOE facilities must not exceed those amounts that would cause any member of the public to receive an effective dose equivalent of greater than 10 mrem/yr.

State air emission permits for the Analytical Chemistry Laboratory, Boiler Plant, Petrology Laboratory, and Baghouse require that emissions be visually monitored for opacity. Emissions cannot exceed 20 percent opacity.

DOE Order 5400.5, dealing with radiation protection of the public and environment, places a limit of 100 mrem/yr (all exposure modes) effective dose equivalent to members of the public as a consequence of DOE activities. In addition, DOE Order 5400.5 lists Derived Concentration Guides (DCG) for air that provide reference values for conducting radiological environmental protection programs. The DCG values for currently monitored radionuclides are presented in Table 5-2.

Table 5-2. DCG Values for Currently Monitored Radionuclides for the GJPO/GJPORAP

Radionuclide	Inhaled Air DCG (μCi/mL)
Thorium-230	4×10^{-14}
Radium-226	1×10^{-12}
Uranium	2×10^{-12}
Radon	3×10^{-9}

5.1.2.2.2 *Sampling Plan*

The three air particulate sampling stations (Figure 5-1) will be run continuously for a 5-day period once a month. Filters collected during this sampling period will be analyzed for radium-226, thorium-230, and uranium. Every sixth day, the samplers will be operated for a 24-hour period, and filters will be analyzed for PM_{10} particulate matter.

Sample collection, sampler maintenance, sampler calibration, and documentation requirements for high-volume air particulate sampling are described in the *Sampling and Analysis Plan for Environmental Monitoring* (Chem-Nuclear Geotech, Inc. 1992a). Air particulate filters are analyzed in accordance with the *Analytical Chemistry Laboratory Administrative Plan and Quality Control Procedures* (Chem-Nuclear Geotech, Inc. 1992f), and the *Analytical Chemistry Laboratory Handbook of Analytical and Sample-Preparation Methods* (Chem-Nuclear Geotech, Inc. 1992e). Laboratory QC measures, which include the analysis of method blanks and known samples, are outlined in the former document. Reporting limits for air effluent analytes are listed in Table 5-3. Field QC measures include the submittal of one PM_{10} filter blank for every 35 filters collected and one radioparticulate filter blank for every 24 filters collected.

Table 5-3. Reporting Limits for Air Effluent Analytes, GJPO/GJPORAP

Constituent	Reporting Limit
Radium-226	4 pCi/filter
Radon	0.07 pCi/L
Thorium-230	0.2 pCi/filter
Uranium	1 μg/filter

Atmospheric radon sampling will continue at the 13 locations (7 on site, 6 off site) shown in Figure 5-2. Detectors will be analyzed quarterly (3-month exposure).

This sampling strategy will continue until the end of GJPORAP, at which time the environmental radon monitoring will be revised to reflect reduction of possible air contaminant sources. The environmental radon sampling program will then focus on environmental surveillance rather than monitoring the uranium mill tailings piles.

The radon detectors are exposed in duplicate (for QC purposes) at each sampling location. The collection and handling of the detectors is outlined in the *Sampling and Analysis Plan for Environmental Monitoring* (Chem-Nuclear Geotech, Inc. 1992a). Radon is monitored with Landauer, RadTrak detectors, which are analyzed by Landauer, Inc., a subcontracted laboratory. Analytical procedures used by the Landauer, Inc. laboratory

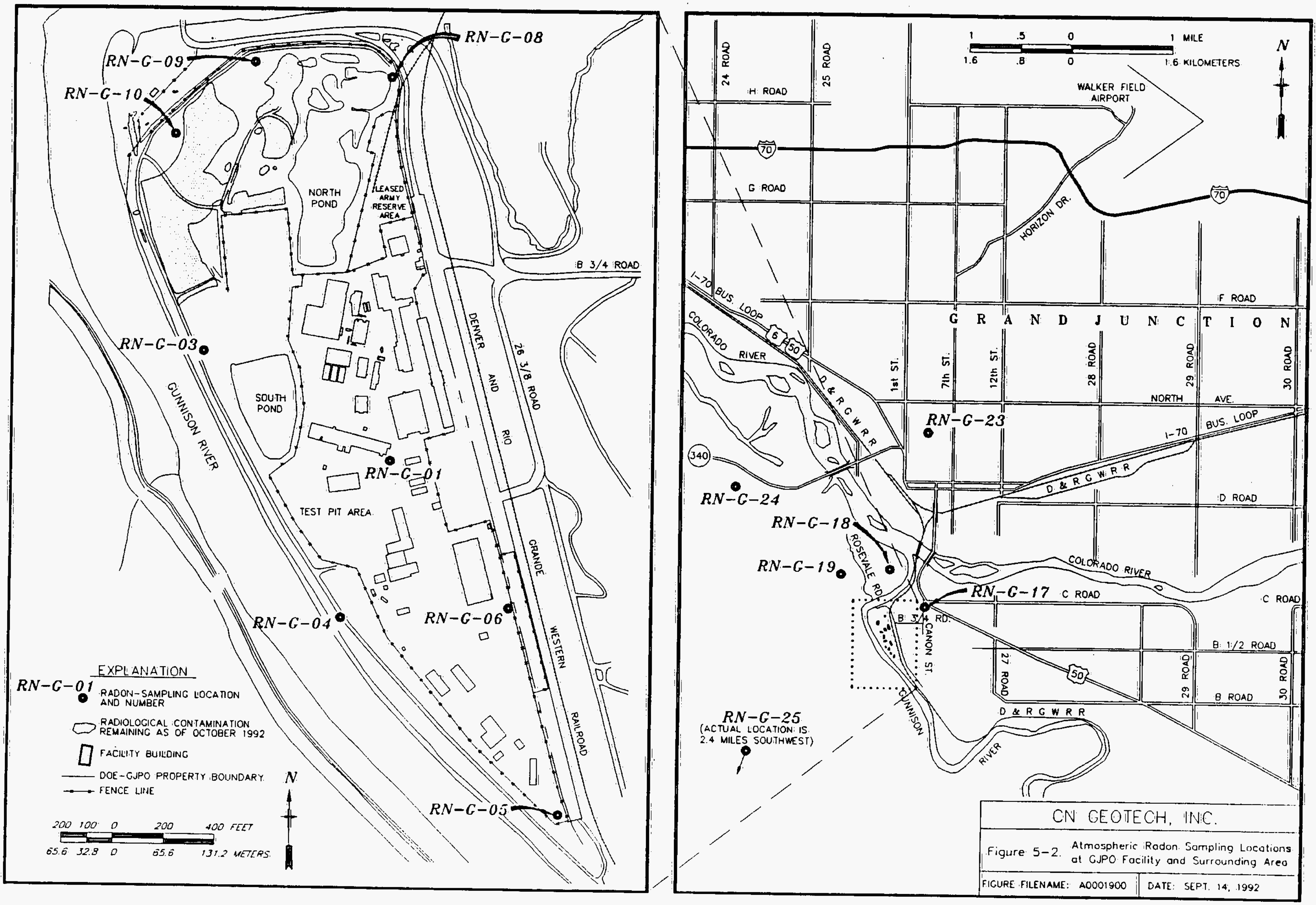

Figure 5-2. Atmospheric Radon Sampling Locations at the GJPO Facility and Surrounding Area

are described in the *Quality Assurance Manual for Radon Monitoring, Revision Number 7* (Landauer, Inc. 1991). The reporting limit for radon is listed in Table 5-3.

Emission monitoring of the Baghouse stack will be continuous at the location shown in Figure 5-1. Radionuclide emission rates will be sampled according to the procedures specified in 40 CFR Part 61.93(b) and to the QA/QC performance requirements specified in 40 CFR Part 61, Appendix B, Method 114. Baghouse filters will be analyzed for radium-226, total uranium, thorium-230, thorium-232, lead-210, and polonium-210. Filters will be collected every two weeks and will be analyzed by the Geotech Analytical Chemistry Laboratory, which uses the procedures in the *Analytical Chemistry Laboratory Handbook of Analytical and Sample-Preparation Methods* (Chem-Nuclear Geotech, Inc. 1992e). This handbook describes the precision of each analytical technique and the methodology and reporting limits used by the laboratory. Detailed procedures for sampling the Baghouse are in the *Sampling and Analysis Plan for Environmental Monitoring* (Chem-Nuclear Geotech, Inc. 1992a). Baghouse data will be used as an input parameter in required dose models to demonstrate compliance with the radiation protection standards established in DOE Order 5400.5 and 40 CFR Part 61, Subpart H.

To comply with the requirements of state air emissions permits, opacity monitoring will be conducted monthly for the Analytical Chemistry Laboratory, Boiler Plant, Petrology Laboratory, and Baghouse. Emissions from these sources will be monitored visually by Geotech personnel who are certified by the Colorado Department of Health to perform opacity inspections. Observations will be recorded in a permanent log book maintained by the Environmental Services Section of Geotech.

5.1.2.2.3 *Data Management*

The Data Manager, appointed by the Geotech Project Manager, will maintain a data base for all air effluent monitoring data. Data will be stored in an ORACLE data base on a MicroVax computer system and will be backed up weekly. All paper reports, records, and data will be centralized in a permanent project file in Geotech's Records Management Section.

5.1.2.2.4 *Data Analysis/Reporting Format*

Data will be analyzed to determine if the monitoring objectives have been met. Only data of known quality will be used to determine whether DQOs have been met. Air effluent data will be compared to the standards listed in Section 5.1.2.2.1 and will be input into an EPA-approved dose model (MICROAIRDOS) to demonstrate compliance with the public radiation dose limitations of DOE Order 5400.5 and 40 CFR Part 61, Subpart H. Compliance with standards will be achieved if all measured and modeled values fall below the standard values. Air effluent data will be reported in the graphical format displayed in Figure 3-3 (Section 3.2.2.2.4), wherein measured and standard values are compared. All monitoring data will be tabulated and reviewed quarterly, and a summary of the data will be presented in the Annual Site Environmental Report.

5.1.2.3 Responsible Organizations

The air effluent monitoring program is the responsibility of the DOE-GJPO Manager. The Geotech Program Manager directs the Geotech Project Manager with the appropriate expertise to complete the necessary requirements of the air effluent monitoring program. Responsibility for the air effluent monitoring program currently resides with the Environmental Services Section of Geotech. (An organization chart is provided in Appendix A).

5.1.3 MMTS

The tailings piles at the Monticello Millsite are currently being monitored from an environmental surveillance standpoint, a strategy justified by the presence of an earthen cover over the tailings piles and no remedial activity of the piles. However, both the air particulate monitoring program and the environmental radon monitoring program will change from a surveillance mode to an effluent monitoring mode when the tailings piles are moved. During tailings movement, it is anticipated that an increase in radiological and non-radiological particulates and radon will be generated. If necessary, the air particulate sampling network will be upgraded and the sampling frequency increased. The number of atmospheric radon monitoring locations also will be increased at that time.

5.2 ENVIRONMENTAL SURVEILLANCE

5.2.1 Regulatory Requirements

Regulatory requirements for air environmental surveillance are outlined as ARARs in Table 5-4. Air environmental surveillance at the GJPO/GJPORAP and the MMTS is conducted to comply with all applicable local, state, and federal regulatory requirements.

5.2.2 GJPO/GJPORAP

Radiological and nonradiological air contaminants at the GJPO/GJPORAP are currently being monitored through the Air Effluent Monitoring Program (Section 5.1.2). Once the remedial activities of GJPORAP are completed, an air environmental surveillance program will be initiated to reflect the reduction of potential air contaminant sources. The air particulate sampling program and the environmental radon sampling program will then be geared toward environmental surveillance rather than monitoring specific air effluent sources.

Table 5-4. ARARs for Air Environmental Surveillance

Standard, Requirement, Criterion, or Limitation	Citation	Description
ARARs Specific to the MMTS		
General Environmental Protection Program	DOE 5400.1 Chapter IV Part 8b	Ambient air quality monitoring should be designed to accomplish the following: 1. Establish background concentration levels of pertinent chemical species. 2. Determine the highest concentrations of the pertinent chemical species expected to occur in the vicinity of DOE operations. 3. Determine representative pollutant concentrations at areas where public health and other concerns should be considered. 4. Evaluate the effects of emissions on ambient levels of pertinent contaminants.
Radiation Protection of the Public and the Environment	DOE 5400.5 Chapter I Part 8a Chapter II Part 1a (1)	Demonstration of compliance with the requirements of this order generally will be based on calculations that make use of information obtained from monitoring and surveillance programs. The ability to detect, quantify, and adequately respond to unplanned releases of radioactive material to the environment relies on in-place effluent monitoring of environmental transport and diffusion conditions and assessment capabilities.

Table 5-4 (continued). ARARs for Air Environmental Surveillance

Standard, Requirement, Criterion, or Limitation	Citation	Description
Radiological Effluent Monitoring and Environmental Surveillance	DOE Environmental Regulatory Guide Chapter 5.0	An evaluation shall be conducted and used as the basis for establishing an environmental surveillance program for all DOE-controlled sites to provide compliance with all applicable environmental regulations. The extent of each environmental surveillance program is to be determined by the responsible field organization, based on applicable regulations, the hazard potential of the effluents, the quantities and concentrations of effluents, and the nature of potential or actual impacts on air, land, biota, and water. The results of this evaluation shall be documented in the site's Environmental Monitoring Plan.
Radiological Effluent Monitoring and Environmental Surveillance	DOE Environmental Regulatory Guide Chapter 5.0	Because air is a primary exposure pathway to humans from radionuclides released to the atmosphere, environmental air sampling should be conducted to evaluate potential doses to environmental populations from inhaled or ingested radionuclides or from external radiation.
National primary and secondary ambient air quality standards	40 CFR Part 50	National primary ambient air quality standards define levels of air quality that the Administrator judges to be necessary to protect the public health. National secondary air quality standards define levels of air quality that the Administrator judges to be necessary to protect the public welfare from any known or anticipated adverse effects of a pollutant.

5.2.3 MMTS

5.2.3.1 Historical Air Environmental Surveillance

Historical air environmental surveillance has been conducted for air particulates and atmospheric radon. Surveillance activities monitored the ambient air impacts from the existing tailings piles and contaminated soil in the vicinity of the Monticello Millsite. In addition, radiologically contaminated soil from the Monticello Vicinity Properties Project is being placed at the Monticello Millsite for temporary storage, and the impact of this activity on the ambient air quality has been monitored.

The MMTS air particulate sampling program was initiated in August 1983. The objective of the air particulate sampling program was the surveillance of ambient air quality to determine impacts from the Monticello Millsite and adjacent contaminated soils, as well as impacts from the placing of Monticello Vicinity Properties contaminated soil and mill tailings at the Monticello Millsite. Environmental surveillance of ambient air quality through the air particulate monitoring program also demonstrated compliance with federal ambient air quality regulations (40 CFR Part 50) and DOE Order 5400.5, both of which deal with radiation protection of the public and environment.

Meteorological wind-rose data collected on site have clearly identified two principal wind vectors in the area. Two air sampling stations (stations AIR-M-4 and AIR-M-5) are located along these two principal wind directions downwind from the millsite. The third sampling station (AIR-M-6) is a background site located approximately 480 meters (0.3 mile) west of the city of Monticello (Figure 5-3).

Historically, the network of samplers ran every sixth day for 24 hours. The sampler flow rate was calibrated at 40 standard cubic feet per minute. The air samplers were mounted on 2.5-meter (8-foot) towers and were equipped with a size-selective inlet that allowed only particles with a diameter of less than or equal to 10 μm to be sampled. Radiological particulate analysis was conducted for uranium, thorium-230, and radium-226, and nonradiological parameters included lead and PM_{10} particulate matter. Concentrations of air particulates never exceeded the standards established by 40 CFR Part 50 and DOE Order 5400.5.

In January 1992, the air particulate monitoring strategy was revised. Because the 24-hour sampling period required for PM_{10} sampling was not long enough to allow radioparticulate accumulations to reach measurable levels, radioparticulate sampling was begun on a separate schedule. Samplers were run continuously for a 5-day period each month for the purpose of radioparticulate sampling only. The frequency of PM_{10} sampling remained at once every sixth day (for a 24-hour period). Lead was removed from the analyte list because measured levels of this particulate were consistently several orders of magnitude below established standards. It will be added to the list again when remedial activities on the millsite begin.

The environmental radon monitoring program was initiated in Monticello in 1984. From 1984 to 1990, measurements were taken with Terradex Track Etch detectors. The

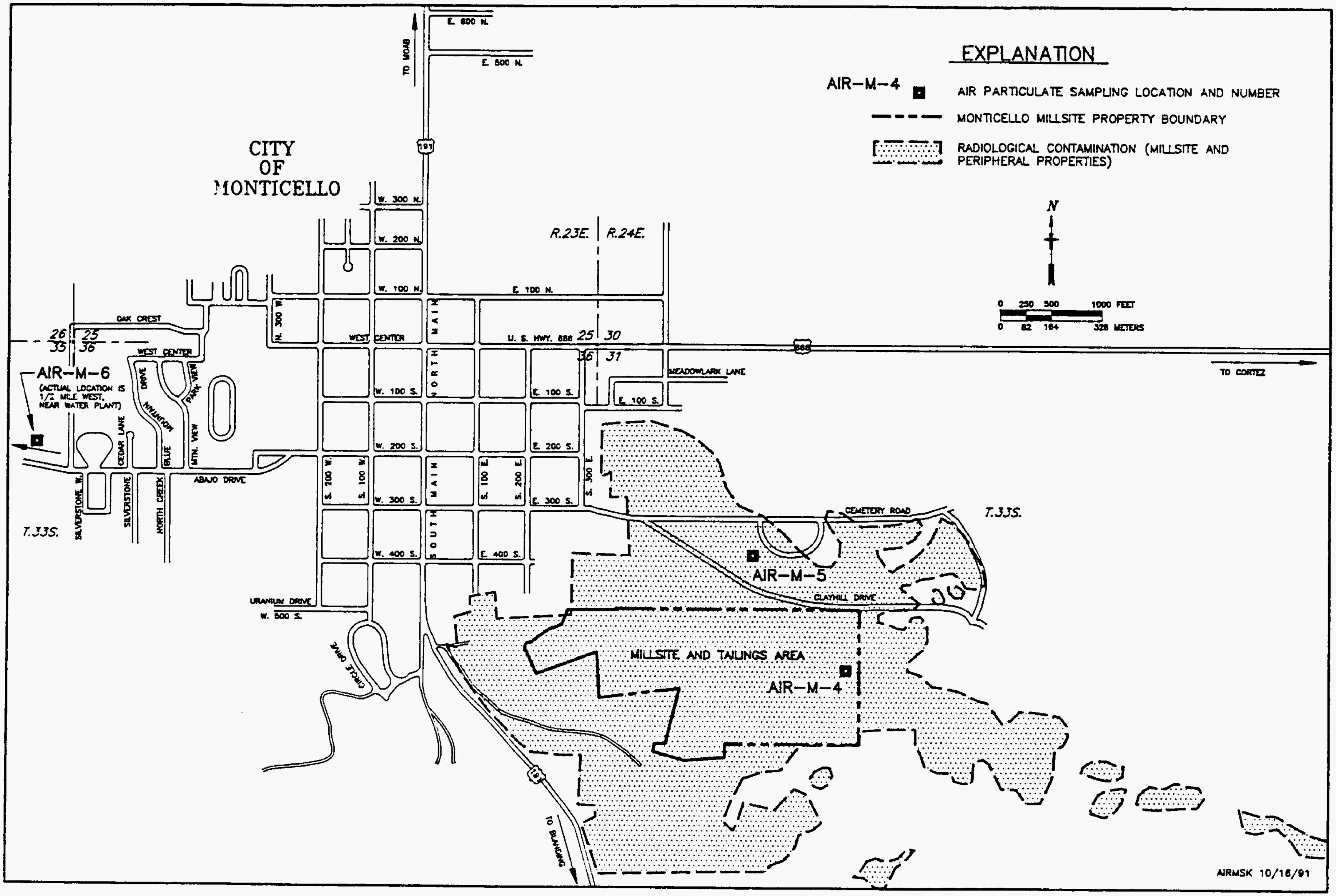

Figure 5-3. Air Particulate Sampling Locations at the Monticello Millsite

detectors were exposed in duplicate and positioned 1 meter above the ground at the locations shown in Figure 5-4. The number of samples was reduced from 19 to 8 at the conclusion of the 1984 sampling period. During the first quarter of 1991, the brand of detectors was changed to Landauer, RadTrak radon detectors. Annual average radon concentrations have been consistent from year to year, indicating a constant rate of radon emission from the piles. Atmospheric radon levels at monitoring locations RN-M-04 and RN-M-07 have regularly exceeded the guidelines established by DOE Order 5400.5.

5.2.3.2 Planned Air Environmental Surveillance

5.2.3.2.1 *Monitoring Objectives*

The objectives of the air environmental monitoring program for the MMTS are

1. to establish a baseline of air quality conditions that exist at the Monticello Millsite and vicinity; and

2. to verify compliance with federal ambient air quality standards, federal radiation protection standards, and DOE orders dealing with radiation protection of the public.

Historical air environmental surveillance has accomplished both monitoring objectives; the objective of current and future monitoring will be to continue to evaluate compliance.

National primary and secondary ambient air quality standards are established under Section 109 of the Clean Air Act. The standard for PM_{10} particulate matter specifies an annual average of not more than 50 $\mu g/m^3$ and a 24-hour maximum concentration not to exceed 150 $\mu g/m^3$.

DOE Order 5400.5, which deals with radiation protection of the public and the environment, places a limit of 100 mrem/yr effective dose equivalent to members of the public as a consequence of all DOE activities. In addition, DOE Order 5400.5 lists DCGs for air that provide reference values for conducting radiological environmental protection programs. The DCG values for currently monitored radionuclides are in Table 5-5.

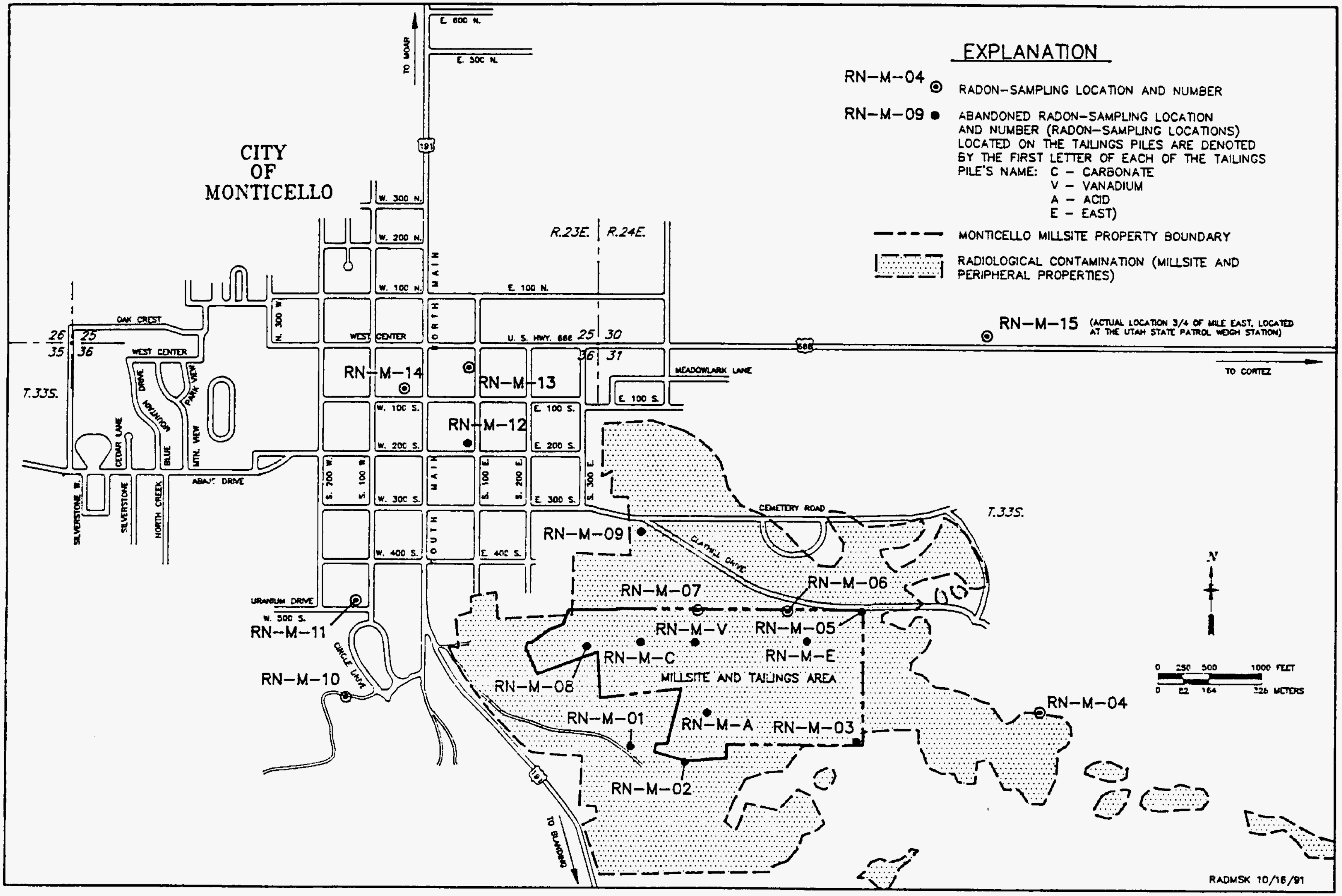

Figure 5-4. Atmospheric Radon Sampling Locations at the Monticello Millsite and Surrounding Area

Table 5-5. Limits for Currently Monitored Radionuclides for the MMTS

Radionuclide	μCi/mL
	Inhaled Air DCG
Thorium-230	4×10^{-14}
Radium-226	1×10^{-12}
Uranium	2×10^{-12}
	Federal Standard (40 CFR 192)
Radon	0.5×10^{-9}

5.2.3.2.2 *Sampling Plan*

The air particulate sampling program will continue to operate as it has since January 1992 until remedial action begins. PM_{10} sampling will be conducted every sixth day, for a 24-hour period, and radioparticulate sampling will be conducted once a month for a continuous 5-day period. Filters will be analyzed for radium-226, thorium-230, and total uranium. Air particulate sampling will be suspended during the winter months because of snow cover and a lack of remedial activity.

When the millsite tailings piles are moved to the permanent repository, the monitoring strategy for the air particulate monitoring program will change from an environmental surveillance mode to an effluent monitoring mode. The tailings piles will then be viewed as a diffuse effluent source as described in DOE's *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (US-DOE 1991). The air sampling network will be upgraded, if necessary, and the frequency of sampling will be increased to closely monitor particulate matter generated as a result of the remedial activities.

Sample collection, sampler maintenance, sampler calibration, and documentation requirements for high-volume air particulate sampling are in the *Monticello Mill Tailings Site and Proposed Repository, Monitoring of Air Particulate, Radon and Gamma Radiation Emissions Work Plan* (Chem-Nuclear Geotech, Inc. 1992h). The air particulate filters are analyzed in accordance with the *Analytical Chemistry Laboratory Administrative Plan and Quality Control Procedures* (Chem-Nuclear Geotech, Inc. 1992f) and the *Analytical Chemistry Laboratory Handbook of Analytical and Sample-Preparation Methods* (Chem-Nuclear Geotech, Inc. 1992e). Laboratory QC measures, which include the analysis of method blanks and known samples, are outlined in the former document. Reporting limits for air monitoring analytes are listed in Table 5-3. Quality control measures include the submittal of one PM_{10} filter blank for every 35 filters collected and one radioparticulate filter blank for every 24 filters collected.

The environmental radon sampling program will remain the same until the tailings piles are moved. The detectors will be exposed in duplicate (for QC purposes) at eight sampling locations, shown in Figure 5-4. The detectors will be collected and analyzed quarterly. Collection and handling of the detectors is outlined in the *Monticello Mill Tailings Site and Proposed Repository, Monitoring of Air Particulate Radon, and Gamma Radiation Emissions Work Plan* (Chem-Nuclear Geotech, Inc. 1992b). Radon will be monitored with Landauer, RadTrak detectors, which are analyzed by Landauer, Inc., a subcontracted laboratory. Analytical procedures used by the Landauer, Inc. laboratory are described in the *Quality Assurance Manual for Radon Monitoring, Revision Number 7* (Landauer, Inc. 1991). The reporting limit for radon is listed in Table 5-3.

When the millsite tailings piles are moved to the permanent repository, the strategy for the environmental radon monitoring program will change from an environmental surveillance mode to an effluent monitoring mode. The tailings piles will then be viewed as an effluent source. The number of sampling locations will be increased to allow for an assessment of the impact of remedial activities on atmospheric radon concentrations. The final sampling plan will be determined through negotiations with the EPA and State of Utah and will be incorporated into the *Monticello Mill Tailings Site and Proposed Repository, Monitoring of Air Particulate, Radon, and Gamma Radiation Emissions Work Plan* (Chem-Nuclear Geotech, Inc. 1992b).

Data from the environmental monitoring program will be used to demonstrate compliance with DOE Order 5400.5. This regulation requires dose modeling (with an approved model) to members of the public annually.

5.2.3.2.3 *Data Management*

The Data Manager, appointed by the Geotech Project Manager, will maintain a data base for all air monitoring data. Data will be stored in an ORACLE data base on a MicroVax computer system. All records, reports, and data will be centralized in a permanent project file in Geotech's Records Management Section.

5.2.3.2.4 *Data Analysis/Reporting Format*

Data will be analyzed to determine if the monitoring objectives have been met. Only data of known quality will be used for determining whether DQOs have been met. Air data will be compared with the standards reported in Section 5.2.3.2.1 and will be input into an approved dose model (MICROAIRDOS) to demonstrate compliance with the public radiation dose limitations of DOE Order 5400.5. Compliance with standards will be achieved if all measured and modeled values fall below the standard values. Air data will be reported in the graphical format displayed in Figure 3-3 (Section 3.2.2.2.4), which compares measured and standard values. All monitoring data will be tabulated and reviewed quarterly, and a summary of the data will be presented in the Annual Site Environmental Report.

5.2.3.3 Responsible Organizations

The MMTS Air Environmental Surveillance Program is the responsibility of the DOE-GJPO Manager. The Geotech Program Manager directs the Geotech Project Manager with the appropriate expertise to complete the necessary requirements of the air monitoring program. Responsibility for the air monitoring program currently resides with the Environmental Services Section of Geotech. (An organization chart is provided in Appendix A).

6.0 Direct Environmental Radiation

6.0 DIRECT ENVIRONMENTAL RADIATION

6.1 EFFLUENT MONITORING

All direct environmental radiation monitoring for the GJPO, GJPORAP, and MMTS is conducted under the environmental surveillance program.

6.2 ENVIRONMENTAL SURVEILLANCE

6.2.1 Regulatory Requirements

The direct environmental radiation monitoring program for the GJPO/GJPORAP and MMTS is conducted to comply with all ARARs outlined in Table 6-1.

6.2.2 GJPO/GJPORAP

6.2.2.1 Historical Direct Environmental Radiation Monitoring

The direct environmental radiation monitoring program at the GJPO began in April 1991. Radiation measurements were made with $CaSO_4$:Dy (calcium sulfate dysprosium) thermoluminescent dosimeters (TLDs), which were configured to detect gamma radiation. Fifteen monitoring locations (Figure 6-1) on the GJPO and surrounding areas were monitored quarterly (3-month exposure period).

6.2.2.2 Planned Direct Environmental Radiation Monitoring

6.2.2.2.1 *Monitoring Objectives*

The objectives of the direct environmental radiation monitoring program are

1. to provide a means of documenting the radiological conditions at the GJPO Facility and surrounding areas; and

2. to assess the potential gamma radiation dose to persons within the GJPO Facility, in accordance with DOE's *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (US-DOE 1991).

The historical direct environmental radiation monitoring program has accomplished both monitoring objectives. Current and future monitoring will continue to focus on these objectives.

Table 6-1. ARARs for Direct Radiation Monitoring

Standard, Requirement, Criterion, or Limitation	Citation	Description
ARARs Common to the GJPO, GJPORAP, and MMTS		
General Environmental Protection	DOE 5400.1 Chapter IV Part 5b	Environmental surveillance shall be conducted to monitor the effects of DOE activities on on-site and off-site environmental resources.
Radiation Protection of the Public and the Environment	DOE 5400.5 Chapter I Part 8a Chapter II Part 1a	Dose evaluations are required to demonstrate that the exposure to members of the public to radiation sources as a consequence of DOE activities does not cause an effective dose equivalent of greater than 100 mrem/yr. Demonstrations of compliance with the requirements of this order shall make use of information obtained from monitoring and surveillance programs.
Radiological Effluent Monitoring and Environmental Surveillance	DOE Environmental Regulatory Guide Chapter 5.0 Parts 5.1, 5.5, 5.6	An evaluation shall be conducted and used as the basis for establishing an environmental surveillance program for all DOE-controlled sites. One of the "critical pathways" of exposure for population groups living within the vicinity of DOE facilities is exposure to external radiation. For DOE sites, the gamma exposure should be measured or calculated. A primary objective is to assess the actual or potential radiation dose to persons in the site environs.
ARAR Specific to the MMTS		
State of Utah Standards for Protection Again t Radiation	Utah Administrative Codes (R447-15-105)	Limits radiation levels from external sources in unrestricted areas so that it will be unlikely for an individual to receive a dose to the whole body in excess of 0.5 rem in any one year.

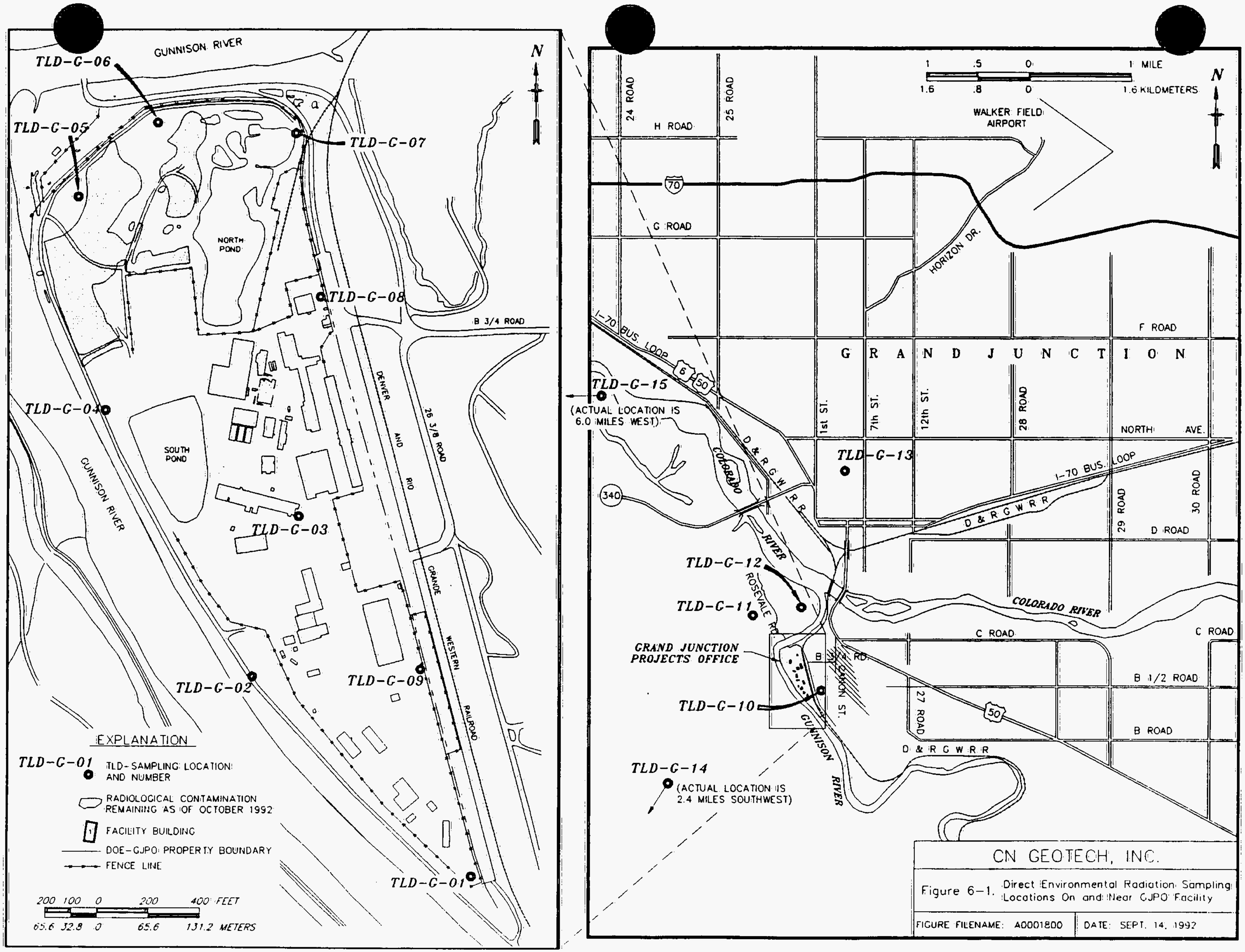

Figure 6-1. Direct Environmental Radiation Sampling Locations On and Near the GJPO Facility

6.2.2.2.2 *Sampling Plan*

The direct environmental radiation monitoring program will continue as it has in the past. The same 15 locations (Figure 6-1) will be monitored for gamma radiation using $CaSO_4$:Dy TLDs. TLDs will be exposed quarterly (3-month exposure period), collected, and sent to Teledyne Isotopes for analysis. New TLDs will be placed in the sampling locations.

Procedures for handling, collecting, and shipping the TLDs are described in the *Sampling and Analysis Plan for Environmental Monitoring* (Chem-Nuclear Geotech, Inc. 1992a). The TLDs are analyzed according to *Preparation and Read-Out of Teledyne Isotopes TLD Card, TIML-TLD-01, Revision 5* (Teledyne Isotopes 1990).

6.2.2.2.3 *Data Management*

The Data Manager, who is appointed by the Geotech Project Manager, will maintain a data base for all direct environmental radiation data. Data will be stored using an ORACLE data base on a MicroVax computer system. All records, reports, and data will be stored in a permanent project file in Geotech's Records Management Section. In addition, all paper documentation will be maintained in a centralized file in the Environmental Services Section.

6.2.2.2.4 *Data Analysis/Reporting Format*

Data will be analyzed to determine if the monitoring objectives have been met. Only data of known quality will be used to determine whether DQOs have been met. Radiological conditions at and near the GJPO Facility will be documented by comparing on- and near-site TLD data with TLD data from background locations. Background locations are 10-15 km (6-9 miles) from the GJPO in areas of typical local geology, similar elevation, and away from buildings. To compare the on- and near-site values to background values, the data will be presented in a tabular format. Additionally, radiation exposure data from the TLDs will be used as one component in the dose evaluation to members of the public, which is not to exceed 100 mrem/yr. By comparing on-site TLD data against background TLD data, an assessment of the potential gamma radiation dose to persons within the GJPO Facility can be made.

6.2.2.3 Responsible Organizations

The direct environmental radiation monitoring program is the responsibility of the DOE-GJPO Manager. The Geotech Program Manager directs the Geotech Project Manager with the appropriate expertise to complete the necessary requirements of the direct radiation monitoring program. The responsibility of the direct radiation monitoring program currently resides in the Environmental Services Section.

6.2.3 MMTS

6.2.3.1 Historical Direct Environmental Radiation Monitoring

The direct environmental radiation monitoring program for the MMTS began in April 1991. Radiation measurements were made with $CaSO_4$:Dy TLDs, which were configured to detect gamma radiation. Thirteen monitoring locations on the Monticello Millsite and surrounding areas (Figure 6-2) were monitored quarterly (3-month exposure period).

6.2.3.2 Planned Direct Environmental Radiation Monitoring

6.2.3.2.1 *Monitoring Objectives*

The objectives of the direct environmental radiation monitoring program are

1. to provide a means of documenting the radiological conditions at the Monticello Millsite and surrounding areas; and

2. to assess the potential radiation dose to persons within the site environs in accordance with DOE's *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (US-DOE 1991).

3. to quantify off-site dose to assess compliance with the 100 mrem/yr dose limit established by DOE Order 5400.5.

The historical direct environmental radiation monitoring program has accomplished these monitoring objectives. Current and future monitoring will continue to focus on these objectives.

6.2.3.2.2 *Sampling Plan*

The direct environmental radiation monitoring program will continue as it has in the past. The same 13 locations (Figure 6-2) will be monitored for gamma radiation using $CaSO_4$:Dy TLDs. The TLDs will be exposed quarterly (3-month exposure period), collected, and sent to Teledyne Isotopes for analysis. New TLDs will be placed in the sampling locations.

Procedures for handling, collecting, and shipping the direct environmental monitoring TLDs are described in the *Monticello Mill Tailings Site and Proposed Repository, Monitoring of Air Particulate, Radon, and Gamma Radiation Emissions Work Plan* (Chem-Nuclear Geotech, Inc. 1992b). The TLDs are analyzed according to *Preparation and Read-Out of Teledyne Isotopes TLD Card, TIML-TLD-01, Revision 5* (Teledyne Isotopes 1990).

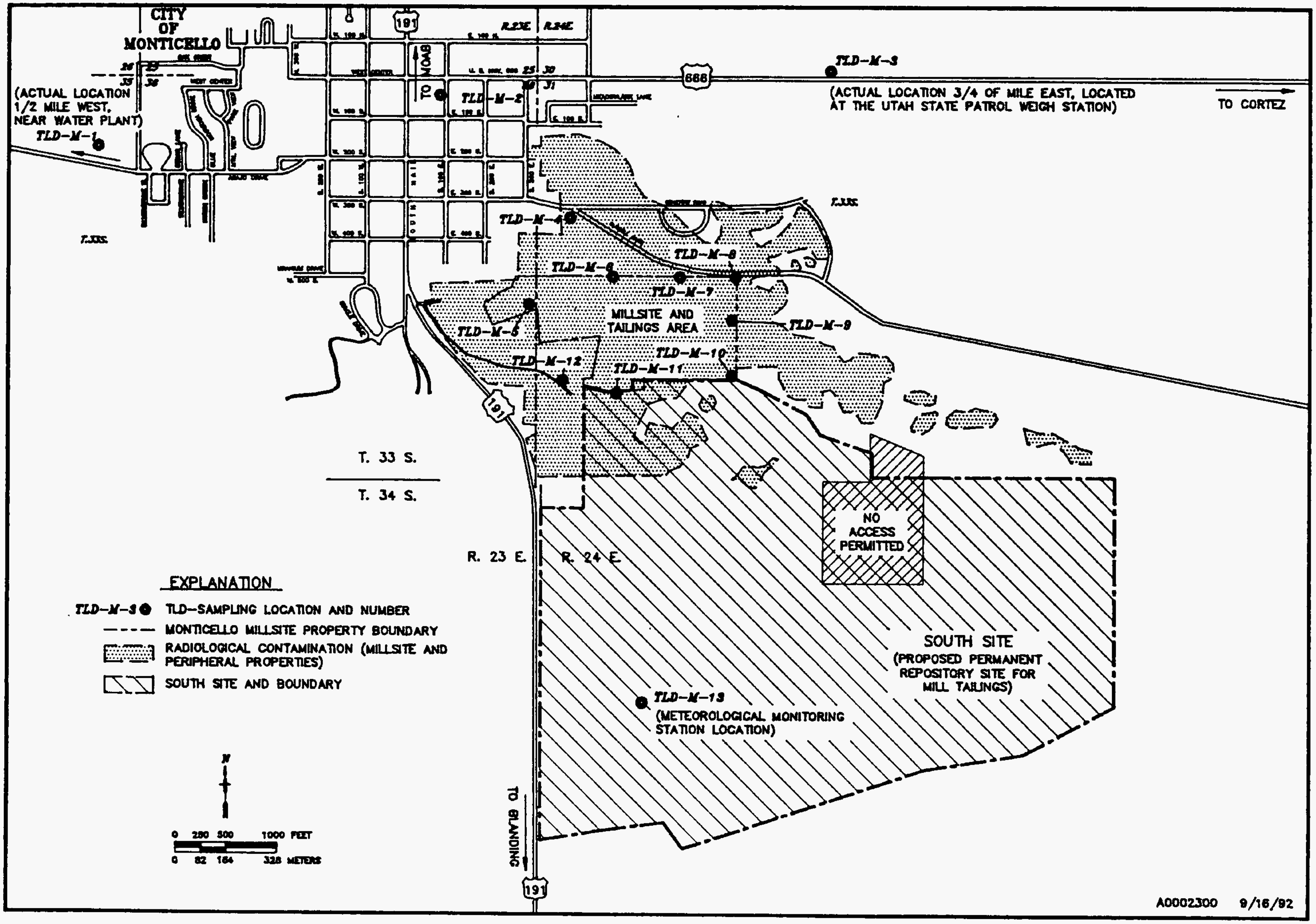

Figure 6-2. Direct Environmental Radiation Sampling Locations at the Monticello Millsite and Surrounding Area

6.2.3.2.3 *Data Management*

Data management procedures will be the same as that described for the GJPO/GJPORAP in Section 6.2.2.2.3.

6.2.3.2.4 *Data Analysis/Reporting Format*

Data analysis and reporting formats will be the same as those described for the GJPO/GJPORAP in Section 6.2.2.2.4.

6.2.3.3 Responsible Organizations

Responsible organizations will be the same as those described for the GJPO/GJPORAP (Section 6.2.2.3).

7.0 Biota

7.0 BIOTA

7.1 GJPO/GJPORAP

A baseline biota study for the GJPO Facility will be conducted during fiscal year 1993-1994 either by Geotech personnel or by a qualified subcontractor. Although there is no human consumption of plants or animals living on or immediately adjacent to the GJPO, and the human health risks are considered to be low, the regulatory need for a radiological ecosystem surveillance program that will better define the impacts of site-derived contamination on biota in the vicinity of the GJPO will be investigated. A draft, *Strategy for Radiological Surveillance of Biota at the Grand Junction Projects Office Facility* (Chem-Nuclear Geotech, Inc. 1992k), was prepared in June 1992; field work will begin after DOE-GJPO approves the strategy plan. Because of seasonal factors, a year's time may be required to adequately evaluate species frequency, pattern of occurrence, and radiological effects; therefore, the final report may not be completed until the fall/winter of 1993.

7.2 MMTS

Baseline biota studies were conducted on and near the Monticello Millsite during 1987 and 1988. Results of those vegetation, wildlife, and aquatic biology surveys were presented in the MMTS Final RI/FS--EA (UNC Geotech 1990c). In a subsequent public health evaluation, it was determined that airborne radiological contaminants did not occur above background concentrations and would not adversely affect the existing biota (UNC Geotech 1990c). The effects on biota from radiological contamination of the ground and surface waters at the millsite have not been assessed. A draft work plan to examine these effects will be prepared in July 1993.

8.0 Quality Assurance

8.0 QUALITY ASSURANCE

Geotech has a Quality Assurance Program (QAP) that is consistent with and responsive to DOE Order 5700.6C, *Quality Assurance,* and that addresses the requirements of ASME NQA-1, *Quality Assurance Program Requirements for Nuclear Facilities* (ASME NQA-1 1989) (also see Definitions Section). The *Quality Assurance Manual (Manual 101)* (Chem-Nuclear Geotech, Inc. 1992l) provides a structured approach for the application of QA principles outlined in NQA-1 to all Geotech work. In addition, a Quality Assurance Program Plan addressing the specific needs of the EMP as specified in DOE Order 5400.1 is outlined as Appendix A.

The Geotech QAP addresses organizational responsibility, design, procedures, records, and audits. Elements such as field and laboratory QC, human factors, chain-of-custody, performance reporting, and independent data verification are implemented by the responsible organizations that perform the work.

Certification of the Geotech Analytical Chemistry Laboratory is not required by the State of Colorado, except for public drinking water system testing, which is not applicable to the GJPO Facility. As stated in the *Federal Facilities Agreement* (U.S. EPA and others 1988) between the DOE, EPA, and State of Utah, certification of the Geotech Analytical Chemistry Laboratory also is not required for the Monticello Millsite. The Agreement states only "that laboratories used by DOE for analyses participate in a QA/QC program equivalent to that of, and approved by EPA." Contracted laboratories may be required to have certification for particular programs or projects, and the QA staff is responsible for ensuring that this is a condition of the subcontract.

The Geotech Analytical Chemistry Laboratory performs analyses in support of DOE environmental radiological monitoring programs and participates in the interlaboratory QA program coordinated by the DOE Environmental Measurements Laboratory. The Laboratory also participates in three non-DOE interlaboratory QA programs: (1) EPA Environmental Measurement Systems Laboratory for radioactive materials; (2) American Industrial Hygiene Association Proficiency Analytical Testing Program for airborne metal, silica, and asbestos; and (3) American Industrial Hygiene Association Identification and Quantification of Asbestos on Bulk Materials Program.

An independent data verification program will be developed for all applicable environmental monitoring/surveillance activities. The Geotech Analytical Chemistry Laboratory maintains an internal QC organization to provide independent data review and evaluation of QA data. In its audit program, the QA staff includes an evaluation of the effectiveness of the Analytical Chemistry Laboratory QC Program. The Environmental Services Section provides the personnel with the appropriate technical expertise to perform an overall independent data review of all environmental monitoring programs to provide confidence in the validity and integrity of the reported data, methods, or processes, and to ensure the protection and retrievability of the data.

8.1 REGULATORY REQUIREMENTS

The QA program for environmental monitoring for the GJPO/GJPORAP and the MMTS are conducted to comply with all ARARs outlined in Table 8-1.

8.2 RESPONSIBLE ORGANIZATIONS

The QA program for the EMP is the responsibility of the DOE-GJPO Manager. The Geotech Program Manager directs the Geotech Project Manager with the appropriate expertise to complete the necessary requirements of the QA program. The QA Section staff coordinator will prepare and revise the QAPP at the direction of the Geotech Program Manager to meet the needs of the project. (An organization chart is provided in Appendix A).

Table 8-1. ARARs for Quality Assurance

Standard, Requirement, Criterion, or Limitation	Citation	Description
ARARs Common to the GJPO, GJPORAP, and MMTS		
Quality Assurance	DOE 5700.6C	A quality assurance program shall be established from which operational programs will benefit by enhancing quality, productivity, and cost effectiveness.
General Environmental Protection Program	DOE 5400.1 Chapter II Part II	A quality assurance program shall include sampling, analysis, and data management for both radioactive and nonradioactive effluent and environmental monitoring. A summary of site results and expected results from participation in interlaboratory cross-check programs should be included.
	DOE 5400.1 Chapter IV Part 5(a)(2)	Auditable records shall be established in accordance with requirements of DOE Order 5700.6C.
	DOE 5400.1 Chapter IV Part 10(a)	A quality assurance program consistant with DOE Order 5700.6C shall be established covering each element of environmental and surveilance programs commensurate with its nature and complexity. The quality assurance program shall include, but not be limited to, the following: 1) organizational responsibility; 2) program design; 3) procedures; 4) field quality control; 5) laboratory quality control; 6) human factors; 7) recordkeeping; 8) chain-of-custody procedures; 9) audits; 10) performance reporting; and 11) independent data verification.
	DOE 5400.1 Chapter IV Part 10(b)	DOE and DOE contract laboratories shall confirm the need and apply for any certification requirements with appropraite Federal, State, or local agencies.

Table 8-1 (continued). ARARs for Quality Assurance

Standard, Requirement, Criterion, or Limitation	Citation	Description
General Environmental Protection Program (continued)	DOE 5400.1 Chapter IV Part 10(c)	DOE and contractor laboratories that conduct analytical work in support of DOE environmental radiological monitoring programs for radioactive materials shall participate in the DOE interlaboratory quality assurance program coordinated by DOE Environmental Measurements Laboratory, New York, NY.
	DOE 5400.1 Chapter IV	EH-1, in consultation with the appropriate program senior official and field organization shall develop an independent data verification program as a part of environmental monitoring programs at DOE facilities. The program shall be in place no later than 12 months after effective date of this Order (11-9-88).
Radiological Effluent Monitoring and Environmental Surveillance	DOE Environmental Regulatory Guide Chapters 2-9	General quality assurance program provisions of Chapter 10 shall be followed. Specific quality assurance requirements for the Facilities' environmental monitoring program are contained in the Quality Assurance Plan associated with the site.
	Chapter 4, Section 4.11	General quality assurance program provisions of Chapter 10 shall be followed. Guidance in quality assurance related to meteorlogical measurements and data processing may be found in Finkelstein et al. (1983).
	Chapter 10 Section 10.1	A quality assurance plan shall be prepared and included as a section in the Environmental Monitoring Plan and shall cover the monitoring activities at each site as described by ASME NQA-1 in the 18-criterion structure of 10 CFR 50.

Table 8-1 (continued). ARARs for Quality Assurance

Standard, Requirement, Criterion, or Limitation	Citation	Description
Radiological Effluent Monitoring and Environmental Surveillance (continued)	Chapter 10 Section 10.1	Periodic audits shall be performed to verify compliance with operational procedures, and all aspects of the QA program. a) These audits shall be performed independently in accordance with written procedures or check-lists by personnel who do not have direct responsibility for performing activities being audited. b) Audit results shall be documented and reported to and reviewed by responsible management. c) Follow-up action shall be taken where indicated.
	Section 10.2	Applicable existing QA requirements on all DOE programs, including monitoring and surveillance, which come from DOE field organizational orders, contractor corporate QA programs, and environmental legistration QA requirements shall be followed.
	Section 10.3	1. Specific operational and QC procedures are required to be documented in the Environmental Monitoring Plan.

Table 8-1 (continued). ARARs for Quality Assurance

Standard, Requirement, Criterion, or Limitation	Citation		Description
Radiological Effluent Monitoring and Environmental Surveillance (continued)	DOE Environmental Regulatory Guide Chapter 10 Section 10.3	a)	Required written procedures cover the following topics: 1) environmental and effluent sampling; 2) ground-water sampling; 3) continuous environmental and effluent monitoring systems; 4) laboratory analysis; 5) data management and calculations; 6) transport and pathway modeling; 7) dose calulations; and 8) review and reporting results.
		b)	Each site is required to maintain an analytical QC program adequate to document and control the accuracy and precision of the analytical results.
		2.	If analytical work is performed by a subcontractor, the subcontractor is required to meet requirements.
		3.	DOE monitoring organizations should participate in other interlaboratory QC programs, such as the EPA Environmental Radioactivity Laboratory Intercomparison Studies Program.
		4.	Radiation measuring equipment, including portable instruments, environmental dosimeters, in-situ equipment, and laboratory instruments, shall be calibrated with standards traceable to the National Institute of Standards and Technology (NIST) calibration standards or equally acceptable (in a case where an NIST standard does not exist) standards.

Table 8-1 (continued). ARARs for Quality Assurance

Standard, Requirement, Criterion, or Limitation	Citation	Description
Radioactive Waste Management	DOE 5820.2A Chapter III Part 3 (1), Chapter V Part 5(e)	Quality assurance shall be consistent with DOE 5700.6C; practices shall be conducted in accordance with applicable requirements of ASME NQA-1 and other national consensus standards.
<u>ARAR Specific to the GJPO/GJPORAP</u>		
National Emission Standards Hazardous Air Pollutants (NESHAPS)	40 CFR Part 61 Subpart H	To determine compliance with the standard, radionuclide emissions shall be determined, and dose equivalents to members of the public shall be calculated using EPA-approved sampling procedures and computer models.
<u>ARAR Specific to the MMTS</u>		
Guidelines and Specifications site-specific for Preparing Quality Assurance Project Plans	EPA QAMS-005/80	Establishes quality assurance guidelines for CERCLA QAPPs; focuses on data quality.

9.0 Records Management

9.0 RECORDS MANAGEMENT

The control of records is essential in providing evidence of technical adequacy and quality for all the EMP activities. During the EMP activities, consistent documentation and accurate record keeping procedures will be implemented. The objectives of a records management program are to maximize the usefulness and protection of important program information and to minimize the record keeping burden and cost. These objectives are achieved through establishment and implementation of continuous, systematic, and effective controls for each phase of a record's life cycle. Records will be legible, identifiable, and retrievable and will be protected against damage, deterioration, or loss.

Records generated in support of the EMP will be subject to the requirements for maximum-level records as described in Section 13 of Geotech's *Management Policies Manual* (Chem-Nuclear Geotech, Inc. 1992m). In conjunction with these requirements, the provisions of the Records Management Plans for the MMTS (Chem-Nuclear Geotech, Inc. 1990b) and the GJPORAP (Chem-Nuclear Geotech, Inc. 1990c) also apply. Records generated in support of the GJPO Facility are subject to the requirements of the *Management Policies Manual* (Chem-Nuclear Geotech, Inc. 1992m). As EMP records are identified, they will be included in the applicable records management program.

10.0 References

10.0 REFERENCES

Abramiuk, I. N., L. A. Blanchfield, E. T. Cotter, H. L. Fleischhauer, C. S. Goodknight, V. G. Johnson, K. E. Karp, P. M. Kearl, N. E. Korte, C. A. Ridolfi, R. R. Roquemore, D. W. Schaer, J. M. Sewell, 1984. *Monticello Mill Tailings Site Site Analysis Report*, GJ-10, prepared for the U.S. Department of Energy, Surplus Management Program, Richland, Washington.

Allen, E. S., and J. Klemenic, 1954. *An Economic Study of the Monticello Carbonate Leach Mill*, unpublished report prepared for the U.S. Atomic Energy Commission, dated November 26.

American Public Health Association, American Water Works Association, and Water Pollution Control Federation, 1985. *Standard Methods for the Examination of Water and Waste*, 16th Edition, American Public Health Association, Washington D. C.

ASME NQA-1, 1989. *Quality Assurance Program Requirements for Nuclear Facilities*, The American Society of Mechanical Engineers, United Engineering Center, New York, NY.

Burchsted, C. A., A. B. Fuller, and J. E. Kahn, 1979. *Nuclear Air Cleaning Handbook*, ERDA-76-21, National Technical Information Service, Springfield, Virginia.

Bendix Field Engineering Corp., 1980. *1979 Environmental Monitoring Report---U.S. Department of Energy Facilities, Grand Junction, Colorado, and Monticello, Utah*, BFEC-1980-3, Bendix Field Engineering Corporation, Grand Junction Operations, Grand Junction, Colorado.

Chem-Nuclear Geotech, Inc., 1990a. *Air Emissions, Annual Report, Calendar Year 1990*, prepared for U.S. Department of Energy, Grand Junction Projects Office, Grand Junction, Colorado.

________________________, 1990b. *Records Management Plan for the Monticello Mill Tailings Site*, P-GJPO-121, Grand Junction, Colorado (internal document).

________________________, 1990c. *Records Management Plan for the Grand Junction Projects Office Remedial Action Project*, P-GJPO-143, Grand Junction, Colorado (internal document).

________________________, 1991a. *1991 National Emission Standards for Hazardous Air Pollutants Subpart H Report,* prepared for U.S. Department of Energy, Grand Junction Projects Office, Grand Junction, Colorado.

Chem-Nuclear Geotech, Inc., 1991b. *Monticello Millsite Environmental Report for Calendar Year 1990*, DOE/ID/12584-87, prepared for U.S. Department of Energy, Grand Junction Projects Office, Grand Junction, Colorado.

________________________, 1991c. *Grand Junction Projects Office Site Environmental Report for Calendar Year 1990*, DOE/ID/12584-88, prepared for U.S. Department of Energy, Grand Junction Projects Office, Grand Junction, Colorado.

________________________, 1992a. *Sampling and Analysis Plan for Environmental Monitoring*, prepared for the U.S. Department of Energy, Grand Junction Projects Office, Grand Junction, Colorado.

________________________, 1992b. Draft *Monticello Mill Tailings Site and Proposed Repository, Monitoring of Air Particulate, Radon, and Gamma Radiation Emissions Work Plan*, prepared for the U.S. Department of Energy, Grand Junction Projects Office, Grand Junction, Colorado.

________________________, 1992c. *Monticello Mill Tailings Site, Operable Unit III, Surface and Ground-Water Remedial Investigation/Feasibility Study Field Sampling Plan*, prepared for U.S. Department of Energy, Grand Junction Projects Office, Grand Junction, Colorado.

________________________, 1992d. *Monticello Millsite Environmental Report for Calendar Year 1991,* prepared for U.S. Department of Energy, Grand Junction Projects Office, Grand Junction, Colorado.

________________________, 1992e (continually updated). *Analytical Chemistry Laboratory Handbook of Analytical and Sample-Preparation Methods*, vols. I and II, Grand Junction, Colorado (internal document).

________________________, 1992f (continually updated). *Analytical Chemistry Laboratory Administrative Plan and Quality Control Procedures*, Grand Junction, Colorado (internal document).

________________________, 1992g. *Grand Junction Projects Office Site Environmental Report for Calendar Year 1991*, prepared for U.S. Department of Energy, Grand Junction Projects Office, Grand Junction, Colorado.

________________________, 1992h. *Monticello Mill Tailings Site, Operable Unit III, Surface-and Ground-Water Remedial Investigation/Feasibility Study Work Plan*, prepared for U.S. Department of Energy, Grand Junction Projects Office, Grand Junction, Colorado.

________________________, 1992i. *Monticello Mill Tailings Site, Operable Unit III, Surface- and Ground-Water Remedial Investigation/Feasibility Study Quality Assurance Project Plan*, prepared for U.S. Department of Energy, Grand Junction Projects Office, Grand Junction, Colorado.

Chem-Nuclear Geotech, Inc., 1992j (continually updated). *Environmental Procedures Catalog*, Grand Junction, Colorado (internal document).

________________________, 1992k. Draft *Strategy for Radiological Surveillance of Biota at the Grand Junction Projects Office Facility*, prepared for U.S. Department of Energy, Grand Junction Projects Office, Grand Junction, Colorado.

________________________, 1992l. (continually updated). *Quality Assurance Manual (Manual 101)*, Grand Junction, Colorado (internal document).

________________________, 1992m. (continually updated). *Management Policies Manual*, Grand Junction, Colorado (internal document).

Finkelstein, P. L., D. A. Mazzarella, T. J. Lockhart, W. J. King, and J. H. White, 1983. *Quality Assurance Handbook for Air Pollution Measurement Systems, Volume IV: Meteorological Measurements*, prepared for U.S. Environmental Protection Agency, Research Triangle Park, North Carolina.

Gilbert, R. O., 1987. *Statistical Methods for Environmental Pollution Monitoring*, Van Nostrand Reinhold Company, New York, NY.

Harcum, J. B., 1990. *Water-Quality Data Analysis Protocol Development*, Ph D. Dissertation, Agricultural and Chemical Engineering Department, Colorado State University, Fort Collins, Colorado.

Henwood, P. and C. Ridolfi, 1986. *Radiological Characterization of the Department of Energy, Grand Junction Projects Office*, GJ-41, Bendix Field Engineering Corporation, Grand Junction Operations, prepared for U.S. Department of Energy, Grand Junction Projects Office, Grand Junction, Colorado.

Korte, N. E., and R. Thul, 1981. *1980 Environmental Monitoring Report--U.S. Department of Energy Facilities, Grand Junction, Colorado, and Monticello, Utah*, BFEC-1981-3, Bendix Field Engineering Corporation, prepared for U.S. Department of Energy, Grand Junction Operations, Grand Junction, Colorado.

____________________, 1982. *1981 Environmental Monitoring Report--U.S. Department of Energy Facilities, Grand Junction, Colorado, and Monticello, Utah*, BFEC-1982-4, Bendix Field Engineering Corporation, prepared for U.S. Department of Energy, Grand Junction Operations, Grand Junction, Colorado.

____________________, 1983. *1982 Environmental Monitoring Report--U.S. Department of Energy Facilities, Grand Junction, Colorado, and Monticello, Utah*, GJO-113(83), prepared for U.S. Department of Energy, Grand Junctions Projects Office, Grand Junction, Colorado.

Korte, N. E., and R. Thul, 1984. *1983 Environmental Monitoring Report--U.S. Department of Energy Facilities, Grand Junction, Colorado, and Monticello, Utah*, GJO-113(84), prepared for U.S. Department of Energy, Grand Junctions Projects Office, Grand Junction, Colorado.

Korte, N. E., and S. Wagner, 1985. *Environmental Monitoring Report on Department of Energy Facilities at Grand Junction, Colorado, and Monticello, Utah for Calendar Year 1984*, GJ-30, prepared for U.S. Department of Energy, Grand Junctions Projects Office, Grand Junction, Colorado.

________________________, 1986. *Environmental Monitoring Report on Department of Energy Facilities at Grand Junction, Colorado, and Monticello, Utah for Calendar Year 1985*, GJ-45, prepared for U.S. Department of Energy, Grand Junctions Projects Office, Grand Junction, Colorado.

Landauer Inc. 1991. *Quality Assurance Manual for Radon Monitoring, Revision Number 7*, Glenwood, Illinois (internal document).

Loftis, J. C., 1990. Personal communication, Colorado State University, Fort Collins, Colorado.

Loftis, J. C., J. Harris, and R. H. Montgomery, 1987. "Detecting Changes in Ground Water Quality at Regulated Facilities," *Ground Water Monitoring Review*, Volume 7:1, 72-76p.

Loftis, J. C., R. C. Ward, R. D. Phillips, and C. H. Taylor, 1989. *An Evaluation of Trend Detection Techniques for Use in Water Quality Monitoring Programs*, EPA/600/3-89/037, prepared for Environmental Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Corvallis, Oregon.

Marutzky, S. J., C. Ridolfi, D. Traub, S. Knutson, and B. W. Walker, 1985. *Radiologic Characterization of the Peripheral Properties Adjacent to the Monticello, Utah, Millsite*, GJ-26, prepared for U.S. Department of Energy, Grand Junction Projects Office, Grand Junction, Colorado.

Sewell, J. M. and L. Spencer, 1987. *Environmental Monitoring Report on Department of Energy Facilities at Grand Junction, Colorado, and Monticello, Utah for Calendar Year 1986*, UNC/GJ-HWMP-2, prepared for U.S. Department of Energy, Grand Junctions Projects Office, Grand Junction, Colorado.

State of Colorado, 1988. *Revised and Amended Rules and Regulations of the Board of Examiners of Water Well Construction and Pump Installation Contractors*, Office of the State Engineer, State Board of Examiners of Water Well Construction and Pump Installation Contractors, Denver, Colorado.

Teledyne Isotopes, 1990. *Preparation and Read-Out of Teledyne Isotopes TLD Card, TIML-TLD-01, Revision 5*, Northbrook, Illinois (internal document).

UNC Geotech, 1988a. *Environmental Monitoring Report on U.S. Department of Energy's Inactive Millsite Facility, Monticello, Utah for Calendar Year 1987*, DOE/ID12584-27, prepared for U.S. Department of Energy, Grand Junctions Projects Office, Grand Junction, Colorado.

____________, 1988b. *Environmental Monitoring Report on U.S. Department of Energy's Grand Junction Projects Office Facility, Grand Junction, Colorado, for Calendar Year 1987*, DOE/ID/12584-24, prepared for U.S. Department of Energy, Grand Junctions Projects Office, Grand Junction, Colorado.

____________, 1989a. *Final Remedial Investigation/Feasibility Study---Environmental Assessment for the U.S. Department of Energy Grand Junction (Colorado) Projects Office Facility*, DOE/EA-0402, prepared for U.S. Department of Energy, Grand Junction Projects Office, Grand Junction, Colorado.

____________, 1989b. *Environmental Monitoring Report on U.S. Department of Energy's Inactive Millsite Facility, Monticello, Utah for Calendar Year 1988*, DOE/ID/12584-41, prepared for U.S. Department of Energy, Grand Junctions Projects Office, Grand Junction, Colorado.

____________,1989c. *Environmental Monitoring Report on U.S. Department of Energy's Grand Junction Projects Office Facility, Grand Junction, Colorado, for Calendar Year 1988*, DOE/ID/12584-40, prepared for U.S. Department of Energy, Grand Junctions Projects Office, Grand Junction, Colorado.

____________, 1990a. *Grand Junction Projects Office Remedial Action Program -- Radiological Assessment for Construction Phase IB*, prepared for U.S. Department of Energy, Grand Junction Projects Office, Grand Junction, Colorado.

____________, 1990b. *Environmental Monitoring Report on U.S. Department of Energy's Inactive Millsite Facility, Monticello, Utah for Calendar Year 1989*, DOE/ID/12584-67, prepared for U.S. Department of Energy, Grand Junctions Projects Office, Grand Junction, Colorado.

____________, 1990c. *Final Remedial Investigation/Feasibility Study---Environmental Assessment for the Monticello, Utah, Uranium Mill Tailings Site*, vols. I and II, DOE/EA/0424, prepared for U.S. Department of Energy, Grand Junction Projects Office, Grand Junction, Colorado.

____________, 1990d. *Environmental Monitoring Report on U.S. Department of Energy's Grand Junction Projects Office Facility, Grand Junction, Colorado, for Calendar Year 1989*, DOE/ID/12584-66, prepared for U.S. Department of Energy, Grand Junctions Projects Office, Grand Junction, Colorado.

____________, 1990e. *Grand Junction Projects Office Ground Water Protection Management Plan*, prepared for U.S. Department of Energy, Grand Junction Projects Office, Grand Junction, Colorado.

U.S. Department of Energy, 1987. *The Environmental Survey Manual*, Appendix E, vol. 4, DOE/EH-0053.

______________________, 1990a. *Declaration for the Record of Decision and Record of Decision Summary--Grand Junction Projects Office Remedial Action Project*, Idaho Operations Office, Grand Junction Projects Office, Grand Junction, Colorado.

______________________, 1990b. *Monticello Mill Tailings Site--Declaration for the Record of Decision and Record of Decision Summary*, DOE/ID/12584-50, Idaho Operations Office, Grand Junction Projects Office, Grand Junction, Colorado.

______________________, 1991. *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance*, Assistant Secretary for Environment, Safety, and Health, Washington D. C.

U. S. Environmental Protection Agency, 1985. *Practical Guide for Groundwater Sampling*, EPA/600/2-85-104.

________________________________, 1986. *Test Methods for Evaluating Solid Waste*, SW-846, Third Edition, November.

________________________________, 1987a. *Data Quality Objectives for Remedial Response Activities*, EPA/540/G-87/003.

________________________________, 1987b. *Handbook - Groundwater*, EPA/625/6-87/016.

________________________________, 1988. *USEPA Contract Laboratory Program Statement of Work for Organics Analyses,* February.

________________________________, 1991. *Guidance Manual for the Preparation of NPDES Permit Applications for Storm Water Discharges Associated with Industrial Activity*, EPA-505/8-91-002.

U.S. Environmental Protection Agency, State of Utah Department of Health, and U.S. Department of Energy, 1988. *Federal Facilities Agreement*, prepared for the Monticello (Utah) Site: Monticello Vicinity Properties NPL Site and Monticello Millsite, December.

Ward, R. C., J. C. Loftis, H. P. Delong, and H. F. Bell, 1990. *Ground Water Quality Data Analysis Protocol*, unpublished paper, Fort Collins, Colorado.

Whitman, A., and R. G. Beverly, 1958. *Radium Balance in the Monticello Acid R.I.P. Uranium Mill*, WIN-113, U.S. Atomic Energy Commission, Raw Materials Development Laboratory.

Appendix A

APPENDIX A

QUALITY ASSURANCE PROGRAM PLAN

for the

ENVIRONMENTAL MONITORING OF GRAND JUNCTION PROJECTS OFFICE FACILITY, GRAND JUNCTION PROJECTS OFFICE REMEDIAL ACTION PROJECT, AND THE MONTICELLO MILL TAILINGS SITE

October 1993

Work Performed Under
DOE Contract DE-AC04-86ID12584

Prepared for
U.S. Department of Energy
Albuquerque Field Office
Grand Junction Projects Office

Prepared by
RUST Geotech Inc.
Grand Junction, Colorado

QUALITY ASSURANCE PROGRAM PLAN
for the
ENVIRONMENTAL MONITORING OF
GRAND JUNCTION PROJECTS OFFICE FACILITY,
GRAND JUNCTION PROJECTS OFFICE REMEDIAL ACTION PROJECT,
AND THE MONTICELLO MILL TAILINGS SITE

POLICY

This Quality Assurance Program Plan (QAPP) identifies and documents the applicable Quality Assurance (QA) requirements of the Geotech QA Program that apply to effluent monitoring and environmental surveillance. It is applicable to the Environmental Monitoring of the Grand Junction Projects Office Facility, Grand Junction Projects Office Remedial Action Project, and the Monticello Mill Tailings Site. This QAPP is one of several planning documents which provide controls for the program. All work performed by RUST Geotech, Inc. (hereafter known as Geotech) on these programs must comply with this QAPP.

Prepared by:

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Ardis K. Rukavina, QA Coordinator — Date

Approved by:

10-14-93
John A. Winterhalder, Manager, Environmental Services — Date

R Eldon Bray — 10-14-93
R.Eldon Bray, DOE Project Manager — Date

The QAPP will be revised by the Quality Assurance Coordinator and the Program Manager to reflect changes in the scope of work.

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FIGURES

1.0 INTRODUCTION

The *Environmental Monitoring Plan* (EMP) has been prepared in accordance with DOE Order 5400.1, *General Environmental Protection Program*. The EMP establishes responsibilities for the effluent monitoring and environmental surveillance associated with the Grand Junction Projects Office (GJPO) Facility, Grand Junction Projects Office Remedial Action Program (GJPORAP), and the Monticello Mill Tailings Site (MMTS).

Reference Implementing Documents

The following Geotech manuals implement portions of the QA Program. These documents will be referenced throughout this QAPP as implementing documents. Section 4.0 contains a complete reference list.

Management Policies Manual (M 100)
Quality Assurance Manual (M 101) Including QA Instructions (QAIs)
Environmental Protection Manual (M 102)
Health and Safety Manual (M 103)
Operation Management Policies Manual (M 104)
Information Services Manual (M 105)
Productivity/Quality Improvement Manual (M 109)
Calibration Control Program for Measuring and Test Equipment and
    Measurement Standards (M 113)
Environmental Procedures Catalog (M 116)
Self Assessment Manual (M 118)

List of Acronyms

DOE - Department of Energy
EMP - Environmental Monitoring Plan
GJPO - Grand Junction Projects Office
GJPORAP - Grand Junction Projects Office Remedial Action Project
MMTS - Monticello Mill Tailings Site
QA - Quality Assurance
QAI - Quality Assurance Instruction
QAPP - Quality Assurance Program Plan
QAPjP - Quality Assurance Project Plan
PQI - Productivity Quality Improvement

1.1 Purpose and Scope

The purpose of the Quality Assurance Program Plan (QAPP) is to define the QA requirements and implementing documents for the EMP. This QAPP is based on the Geotech QA Program as defined in the Geotech *Quality Assurance Manual* (RUST Geotech Inc. 1992b). The Geotech QA Program was developed in response to DOE Order 5700.6C, *Quality Assurance*, and is based on ASME NQA-1. The Geotech QA requirements have been graded to meet the needs of the program.

This QAPP has been prepared to provide assurance that the work performed will be of the quality required to satisfy EMP objectives.

The EMP contains rationale and design criteria for the program, extent and frequency of monitoring and measurements, laboratory analysis procedures, preparation and disposition of reports in order to verify compliance with the applicable local, state and federal laws and regulations, as well as the applicable DOE Orders.

1.2 Revisions

This QAPP is maintained by the QA Coordinator for the Environmental Monitoring Program Manager. It will be revised by the QA Coordinator and the Program Manager as required to meet the needs of the Program. Revisions will require approvals at the same levels as the original document.

2.0 PROGRAM QUALITY LEVEL

The Geotech Program Manager for the Environmental Monitoring Program has determined an overall quality level of "Q" level, as defined in the *QA Manual* (RUST Geotech Inc. 1992b). The "Q" level notifies personnel at a glance that the program may have additional QA requirements. The higher level is applicable for the environmental surveillance and monitoring of GJPO, GJPORAP, and MMTS, because these activities verify compliance for permitting activities.

3.0 PROGRAM QUALITY ASSURANCE REQUIREMENTS

The QA Program is documented in the Geotech *Quality Assurance Manual* (RUST Geotech Inc. 1992b), program-specific QAPPs, and task-specific Quality Assurance Project Plans (QAPjPs). QAPjPs will be prepared for the Environmental Monitoring Program when the need for additional site specific QA requirements are identified.

This QAPP describes the applicable requirements of the *QA Manual* (RUST Geotech Inc. 1992b) through the use of a graded approach. The applicability and level of each criterion of the manual are defined for implementation by the EMP. This section of the QAPP lists each criterion of the manual, states the applicable level (Standard or Q), and provides modifications to the QA requirements as necessary to meet program demands. When the criterion does not apply, an explanation is provided for the Not Applicable designation.

Quality Assurance Instructions (QAIs), which are contained within the *QA Manual* (RUST Geotech Inc. 1992b), and other Company Manuals are referenced throughout this QAPP when applicable.

3.1 CRITERION 1. QUALITY ASSURANCE PROGRAM

Standard Level Requirements, and QAIs 1.1, 1.2, 1.3, 1.4, 1.6, 1.7, 1.9, 1.10, 1.11, 1.12 and Manuals 100, 103, 104, 109, 116, 118 and the Training Catalog apply.

3.1.1 Planning (QAIs 1.2, 1.4 and 1.11, and Manuals 100 and 104)

The Geotech Program Manager is responsible for the preparation of planning documents. The planning documents are to identify the purpose of the program, applicable requirements, assignment of responsibility, schedules, methods to accomplish the work and deliverables.

The following EMP planning documents have been identified:

- Environmental Monitoring Plan for the Grand Junction Projects Office Facility, Grand Junction Projects Office Remedial Action Project, and the Monticello Mill Tailings Site (Oct. 1993).

  Defines the mission and objectives of the EMP.

- Quality Assurance Program Plan for the Environmental Monitoring of Grand Junction Projects Office Facility, Grand Junction Projects Office Remedial Action Project, and the Monticello Mill Tailings Site Revision 03, October 1993 (This document).

  Defines requirements of the Geotech QA Manual which are applicable to the EMP.

Additional planning documents may be prepared or current documents revised as needed to address changes in the requirements or scope of work. The Program Manager will notify the QA Manager of substantial changes to the scope of work. QAI 1.2, Notification of Incoming Work, provides additional guidance to Program Managers.

Geotech's requirements on the contents of planning documents are explained in the QA Manual, QAI 1.11, Administrative and Technical Planning. Planning documents and revisions to the documents will be reviewed by affected organizations and approved by the Program Manager prior to beginning work.

The Program Manager and QA Coordinator will be responsible for maintaining this QAPP. The EMP and the QAPP will be reviewed by affected organizations and the QA Manager. Approval of the Program Manager is required. Review and approval of DOE/GJPO is required. Records of review will be maintained by the Project Manager. Revisions require the same level of approval as the original documents. Details for QAPP preparation can be found in QAI 1.4, Development and Approval of QA Program Plans.

3.1.2 Readiness Reviews (QAI 1.11 and Manual 104)

Prior to the initial monitoring program, a Work Readiness Review will be conducted. The Program Managers are responsible for the selection of the review committee. This committee should be made up of representatives from technical, compliance, and support organizations. The review may include: verification of personnel qualifications, equipment status, review of procedures for applicability, and responsibilities and authorities of the participants. For additional details see QAI 1.11. The review will be conducted in accordance with the *Operations Management Policy Manual* (RUST Geotech Inc. 1991), Work Readiness Reviews, and will be documented.

3.1.3 Training and Qualification (QAIs 1.1 and 1.9, Section 14 of Manual 100, Training Catalog, and Manual 103)

Training needs must be determined by supervisors, and training must be provided to establish and maintain proficiency. Training must be documented. Additional direction is provided by QAI 1.1, Training and Indoctrination of Employees, of the *QA Manual* (RUST Geotech Inc. 1992b).

No program specific training is anticipated. Should special training be needed for the performance of a task, the Program Manager will notify the responsible line manager who is responsible for assuring personnel are trained and qualified.

Section 14 of the *Management Policies Manual* (RUST Geotech Inc. 1992a) details the company wide training policy. The *Training Catalog* (Unnumbered document) provides additional information and guidance related to company-wide, position, and program required training. Training records are maintained by Training and Employee Development. Personnel training status may be verified through that office.

Personnel assigned work within the program will be familiarized with the program planning documents prior to beginning work.

QA audit personnel will be certified as described in QAI 1.9, Certification of Personnel. QA surveillance personnel will be qualified in accordance with internal procedures.

3.1.4 Document Reviews (QAI 1.7 and Manual 100)

Plans, implementing instructions, procurement documents and design documents for this program will be reviewed by the QA Coordinator. These reviews will be performed according to QAI 1.7, QA Review of Documents That Implement the QA Program.

Program planning documents must be reviewed by the affected organizations and comment resolution must be documented. Records showing document review for the current version will be maintained by the originator.

3.1.5 Suspension of Activities (QAI 1.6)

Personnel are encouraged to stop work whenever conditions of an imminent threat to safety, quality or that may have significant environmental impact are identified. The conditions must be reported to the Program manager for evaluation and resolution.

A QA Stop Work Order may be issued when measures to correct adverse conditions have failed. The originator must have the QA Coordinator or QA Manager sign the Stop Work Order before issuance. Guidance on issuing Stop Work Orders is provided in QAI 1.6, Suspension of Activities.

3.1.6 Self-Assessment and Quality Improvement (QAI 1.3 and 1.12 and Manuals 118 and 109)

The Program Manager will evaluate implementation and effectiveness of the QA Program for the EMP as described in QAI 1.3, Management Self-Assessment. The *Self-Assessment Manual* (RUST Geotech, Inc. 1992e) provides detailed guidance for the performance of these assessments.

Quality improvements are encouraged as detailed in QAI 1.12, Quality Improvement. One mechanism is the Productivity and Quality Improvement (PQI) effort. All employees are eligible to submit ideas for improvement using the process defined in the *Productivity/Quality Improvement Manual* (RUST Geotech, Inc. 1992d).

Figure 1, "NQA-1/QAMS-005/DOE Order 5400.1 Comparison," identifies how the Geotech QA Manual as implemented by this QAPP, can be correlated with the Environmental Protection Agency (EPA) guidelines and the Department of Energy Environmental Policy Statement, Quality Assurance and Data Verification.

3.1.7 Implementing Documents (QAI 1.10)

Comparison Matrices are depicted in QAI 1.10, Cognizant Organizations for QA Program Implementation. These matrices show how the *QA Manual* (RUST Geotech Inc. 1992b) implements the requirements of DOE Order 5700.6C and ANSI/ASQC E4. The matrices also list the procedures and/or manuals used throughout the Company to implement the requirements of the *QA Manual* (RUST Geotech Inc. 1992b).

NQA-1/QAMS-005/DOE 5400.1 COMPARISON

CRITERION 1.0 - Organization	4.0 Project Organization and Responsibility	1. Organization
CRITERION 2.0 - Quality Assurance Program	4.0 Project Organization and Responsibility 5.0 QA Objectives for Measurement Data in Terms of Precision, Accuracy, Completeness, Comparability, and Representativeness. 16.0 Quality Assurance Reports to Management	2. Program Design 10. Performance Reporting
CRITERION 3.0 - Design Control	3.0 Project Description and Responsibility 5.0 QA Objectives for Measurement Data in Terms of Precision, Accuracy, Completeness, Comparability, and Representativeness	6. Human Factors
CRITERION 4.0 - Procurement Document Control		
CRITERION 5.0 - Instructions, Procedures, and Drawings	1.0 Title Page with Provisions for Approval Signatures 2.0 Table of Contents 3.0 Project Description and Responsibility 5.0 QA Objectives for Measurement Data in Terms of Precision, Accuracy, Completeness, Comparability, and Representativeness 9.0 Analytical Procedures 10.0 Data Reduction, Validation, and Reporting 14.0 Data Assessment	3. Procedures
CRITERION 6.0 - Document Control	1.0 Title Page with Provisions for Approval Signatures 2.0 Table of Contents 6.0 Sampling Procedures 9.0 Analytical Procedures 10.0 Data reduction, Validation, and Reporting	
CRITERION 7.0 - Control of Purchased Items and Services		
CRITERION 8.0 - Identification and Control of Items	6.0 Sampling Procedures	8. Chain-of-Custody Procedures
CRITERION 9.0 - Control of Processes	4.0 Project Organization and Responsibility 13.0 Preventive Maintenance Procedures and Schedules	
CRITERION 10.0 - Inspection	11.0 Quality Control 13.0 Preventive Maintenance Procedures and Schedules	4. Field Quality Control

Figure 1. NQA-1/QAMS-005/DOE 5400.1 COMPARISON

NQA-1/QAMS-005/DOE 5400.1 COMPARISON

ASME NQA-1	EPA QAMS 005/80	DOE ORDER 5400.1
CRITERION 11.0 - Test Control	6.0 Sampling Procedures 9.0 Analytical Procedures	5. Laboratory Quality Control 11. Independent Data Verification
CRITERION 12.0 - Control of Measuring and Test Equipment	8.0 Calibration Procedures and Frequency	
CRITERION 13.0 - Handling, Storage and Shipping	6.0 Sampling Procedures	
CRITERION 14.0 - Inspection, Test, and Operating Status	7.0 Sample Custody	
CRITERION 15.0 - Control of Nonconforming Items	14.0 Data Assessment	
CRITERION 16.0 - Corrective Action	15.0 Corrective Action 16.0 QA Reports	
CRITERION 17.0 - Quality Assurance Records	16.0 QA Reports	7. Recordkeeping
CRITERION 18.0 - Audits	16.0 QA Reports	9. Audits

References: ASME NQA-1-1989 Edition, Quality Assurance Program Requirements for Nuclear Facilities.

EPA QAMS-005/89, Interim Guidelines and Specifications for Preparing Quality Assurance Project Plans.

DOE 5400.1, General Environmental Protection Program, June 1990.

Figure 1. NQA-1/QAMS-005/DOE 5400.1 COMPARISON (continued)

3.2 CRITERION 2, ORGANIZATION

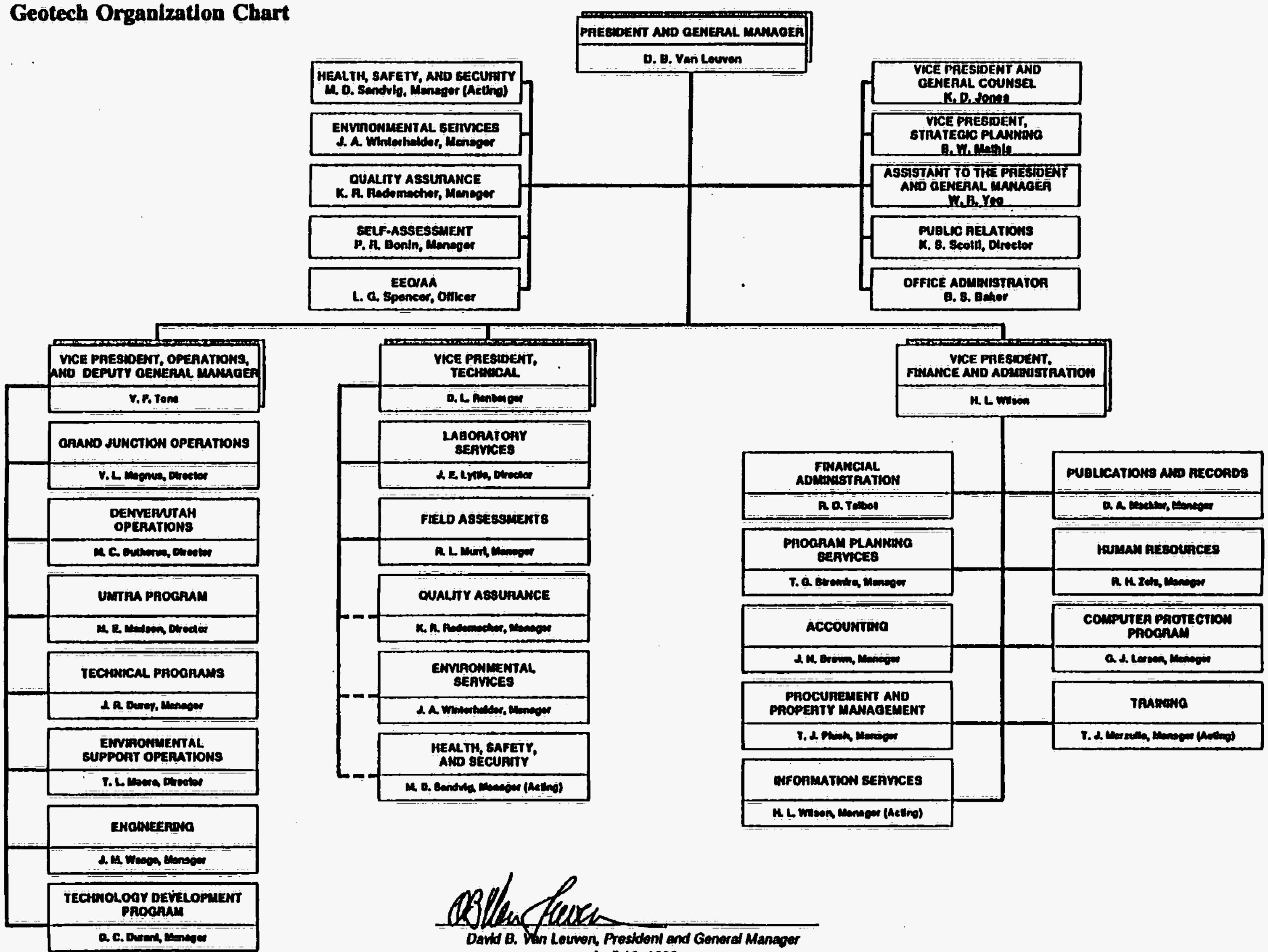
Standard Level Requirements, QAI 2.1 and Manuals 100, and 104 applies

The organizational structure and the assignments of responsibilities will be established in accordance with the following principles:

- Quality performance is achieved, verified, and maintained by the people who perform the work.
- Quality achievement is independently verified by people who are not directly responsible for performing the work.

Geotech's Functional Organization structure, shown in Figure 2, is also contained in the *Management Policies Manual* (RUST Geotech, Inc. 1992) Section 12. The Organizational structures which support the EMP are shown in Figure 3. Geotech Management is responsible for implementing the QA Program. The EMP Program Manager is responsible for assuring the QA Program is adequately defined and implemented for program use through this QAPP.

Geotech Organization Chart



David B. Van Leuven, President and General Manager
April 16, 1993

Figure 2. Geotech Organization

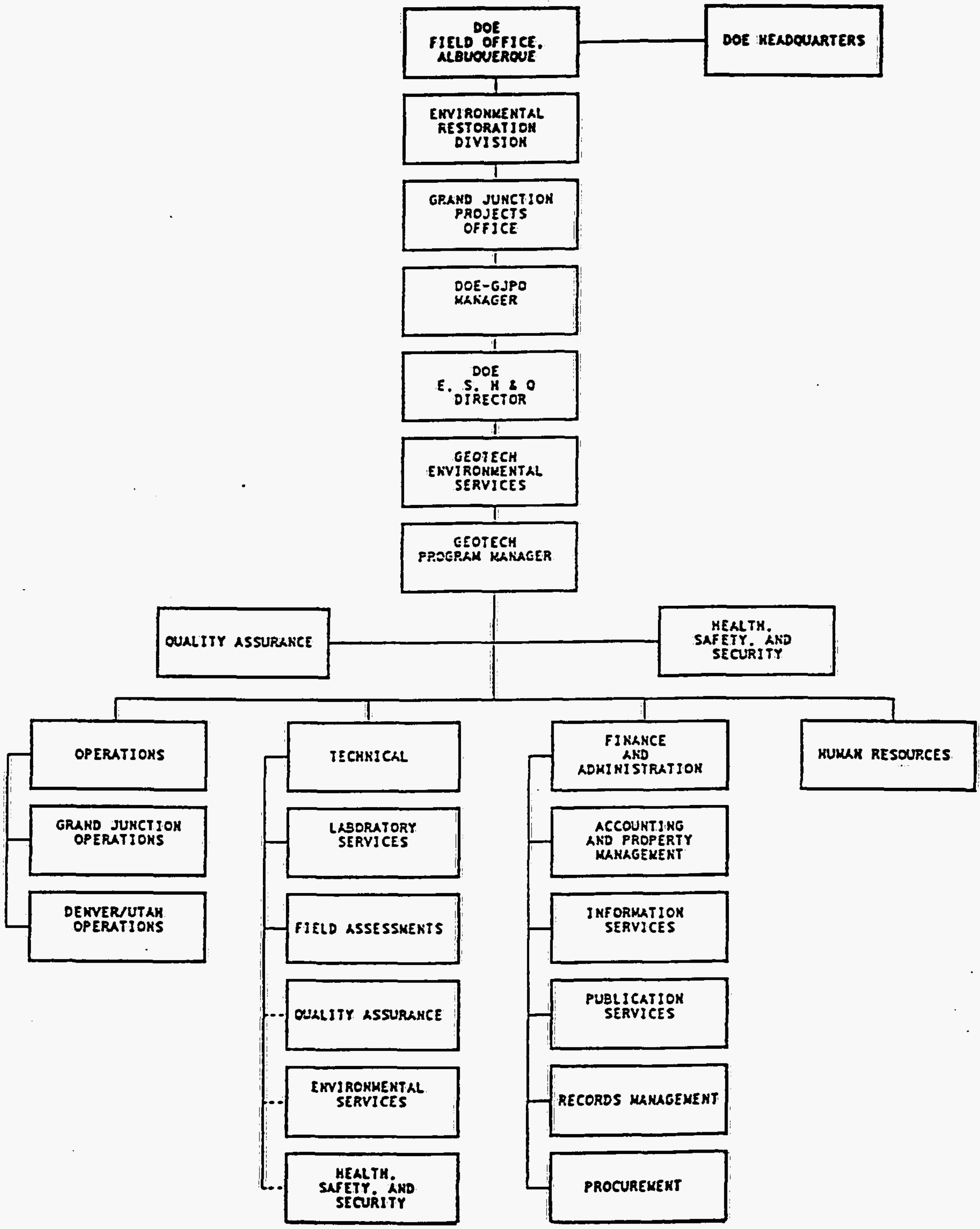


Figure 3. Geotech Organization in Support of the Environmental Monitoring Program

3.3 CRITERION 3, DESIGN CONTROL

Standard Level QA Requirements, QAI 3.1, 3.2, 3.3, and Manual 105 applies

Design output is furnished by the EMP in the form of effluent monitoring and environmental surveillance performance requirements. Should any corrective action be required that results in a design change, the standard requirements of design control will apply.

Computer programs used in modeling or data reduction will be verified or validated before use. The activity manager using the computer program is responsible for software quality control as described in the *Information Services Manual* (RUST Geotech Inc. 1993).

The process for the collection of environmental data will be defined, controlled, verified, and documented. The data collection design process includes the establishment of data quality objectives. The design of data collection systems may be completed at one time or in stages depending on the nature of the work and the information known. The design and documentation will be revised whenever the environmental conditions, data objectives, or data quality objectives have changed.

3.4 CRITERION 4, PROCUREMENT DOCUMENT CONTROL

Standard Level QA Requirements, QAI 4.1, Section 5 of Manual 100 and the *Procurement Manual* applies

The Standard Requirements apply to the procurement of items or services by Geotech. Procurement documents for routine maintenance and minor repair need not to submitted to QA for review. Procurement documents for subcontracted services will require QA review. QA review will assure that the appropriate QA requirements are included in the documents. The Geotech *Management Policies Manual* (RUST Geotech Inc. 1992a) Section 5, implements this requirement.

3.5 CRITERION 5, INSTRUCTIONS, PROCEDURES, AND DRAWINGS

Standard Level QA Requirements, QAI 5.2, Section 2 of Manual 100 and Manual 116 applies when invoked by Project Planning documents.

The work of the EMP will be controlled by instructions, procedures, and drawings to achieve the required quality. Procedures will describe responsibilities and interfaces, delineate the method and sequence, provide acceptance criteria (when applicable), records that will be generated and include provisions for recording of data. QAI 5.2, Preparation of Instructions, Procedures, and Drawings, provides additional information and guidance.

The *Environmental Procedures Catalog* (RUST Geotech Inc. 1992c) contains general field procedures for a variety of tasks. These procedures may be adopted or modified for use with this plan.

Procedures written to control the work for the EMP will comply with the *Management Policies Manual* (RUST Geotech Inc. 1992a), Section 2, which explains the company system for procedures.

3.6 CRITERION 6, DOCUMENT CONTROL

Standard Level QA Requirements and Section 2 of Manual 100 applies

EMP documents will be controlled to assure that current and correct documents are used by those performing the work. Control and distribution of EMP planning documents is the responsibility of Records Management. All requests for these documents must be sent to Records Management who will document the distribution. Records Management maintains records of the distribution.

Support organization procedures will be controlled by those organizations. Section 2 of the *Management Policies Manual* (RUST Geotech Inc. 1992a) provides information for implementation.

3.7 CRITERION 7, CONTROL OF PURCHASED ITEMS AND SERVICES

Standard Level QA Requirements, Section 5 of Manual 100, and the *Procurement Manual* applies

The EMP will plan procurements in accordance with the Procurement Manual. The complexity and importance of procured items and services will determine the extent of control through supplier evaluation and selection, evaluation of supplier performance, and acceptance of items and supplier-generated documents. The method and extent of control of purchased items and services will be determined during procurement planning.

3.8 CRITERION 8, IDENTIFICATION AND CONTROL OF ITEMS AND SAMPLES

Standard Level QA Requirements and Manual 116 applies when invoked by Planning documents.

Individual organizations involved in sampling, testing and materials acceptance are responsible for including specific control, identification, traceability and storage requirements in their instructions, procedures, drawings and other documents that control work.

Samples collected for the EMP will be correctly identified and traceable to the sampling location. Standard procedures maintained in the *Environmental Procedures Catalog* (RUST Geotech Inc. 1992c) will be used by Geotech field personnel for sampling identification, traceability, and control of samples. When appropriate, Chain of Custody procedures will be implemented for samples associated with all environmental monitoring activities.

Identification must be maintained either on or with the sample or in documents that can be traced to the sample. Samples must be identified so as to maintain traceability and clear association with the sampling location.

3.9 CRITERION 9. CONTROL OF PROCESSES

Not Applicable

Process control will be achieved through the use of qualified personnel, instructions, procedures, and drawings. No special processes are anticipated.

3.10 CRITERION 10. INSPECTION

Standard Level QA Requirements, QAI 10.1 applies

The QA Coordinator will conduct surveillances of work in progress to verify compliance with planning documents and implementing procedures. These surveillances will be planned, performed, and documented in accordance with QAI 10.1, QA Surveillances, and QA Desk Instructions. The QA Coordinator will be qualified as defined in the internal QA desk instructions.

3.11 CRITERION 11. TEST CONTROL

Standard Level QA Requirements

The Standard requirements apply to instruments used to collect data in support of EMP activities. Procedures or plans must establish test requirements and acceptance criteria. Test control procedures must be provided to the QA Coordinator for review and comment before use.

Test control elements include data quality objectives (acceptance criteria), test objectives, required instrumentation, equipment calibration, and environmental conditions. The results must be documented and evaluated to assure that test requirements have been met.

Documentation of operational checks and/or standardization must be maintained as detailed in procedures specific to the equipment.

3.12 CRITERION 12, CONTROL OF MEASURING AND TEST EQUIPMENT

Standard Level QA Requirements and Manual 113 applies

The Standard Requirements apply to instruments used to collect data will be controlled to maintain accuracy.

The requirements of the *Calibration and Control Program for Measurement and Test Equipment and Measurement Standards Manual* (RUST Geotech Inc. 1992f) apply to any calibrated instruments that are used.

3.13 CRITERION 13, HANDLING, SHIPPING, AND STORAGE

Standard Level QA Requirements

Handling, shipping, and storage of sensitive, critical, high-value or perishable items will be controlled by the use of procedures. Specific procedures are found in the *Environmental Procedures Catalog* (RUST Geotech Inc. 1992c).

3.14 CRITERION 14, INSPECTION AND TEST STATUS

Not Applicable

Inspection and test status does not apply to the EMP. Measuring and test equipment status is controlled through Criterion 12, Control of Measuring and Test Equipment.

3.15 CRITERION 15, NONCONFORMING ITEMS CONTROL

Standard Level QA Requirements and QAI 15.1 applies

The Standard Requirements apply and are implemented by QAI 15.1, Nonconformance Reporting, Disposition, and Closure. This system will be used to report and evaluate any nonconforming activities, data, or items.

Formal reporting is not required for nonconforming items, data, or activities that are in progress, if discovered before delivery or transmittal to other organizations. These items will be documented and evaluated internal to the organization.

3.16 CRITERION 16, CORRECTIVE ACTION

Standard Level QA Requirements and QAI 16.1 applies

The Standard Requirements apply to the identification of conditions adverse to quality, determination of the cause, and completion of corrective action. QAI 16.1, Corrective Action Request System, is the implementing instruction. Any Corrective Action Request which affects the EMP will be forwarded to the Program Manager for evaluation and corrective action. The QA Coordinator will track and verify the corrective action.

3.17 CRITERION 17, RECORDS

"Q" Level QA Requirements and Section 13 of Manual 100 applies

The records for the EMP have been defined as a "Q" level requirement. The applicable "Q" requirements for the EMP are receipt control, storage procedures, and records storage facilities.

Records must be legible, identifiable, and retrievable. Records are to be protected against damage, deterioration or loss.

The *Management Policies Manual* (RUST Geotech Inc. 1992a), Section 13, Records Management, establishes Company-wide responsibilities for planning, generation, classification, indices, protection, storage, and disposition. The Records Management Plan contained in Section 9.0 of the EMP describes defines specific procedures to be applied to each segment of the EMP.

3.18 CRITERION 18, AUDITS

Standard Level QA Requirements, QAI 18.1 applies

The Standard Requirements and QAI 18.1, Performance and Reporting of Audits, are applicable. Audits will be conducted by qualified auditors. Lead Auditors will be certified (see Criterion 1).

Lead Auditors will be independent of the program, although the QA Coordinator for the program may assist. Technical expertise may be provided by persons outside the QA organization.

Planned and scheduled audits of the program and support organizations will be performed to verify compliance with the QA Program. Surveillances and visits will be scheduled periodically to verify compliance with plans and procedures.

4.0 References

RUST Geotech Inc. 1991. Operations Management Policies Manual (Manual 104), Grand Junction Projects Office (internal document).

____________________, 1992a (continually updated). Management Policies Manual (Manual 100), Grand Junction Projects Office (internal document).

____________________, 1992b (continually updated). Quality Assurance Manual (Manual 101), Grand Junction Projects Office (internal document).

____________________, 1992c (continually updated). Environmental Procedures Catalog (Manual 116), Grand Junction Projects Office (internal document).

____________________, 1992d. Productivity Quality Improvement Manual (Manual 109), Grand Junction Projects Office (internal document).

____________________, 1992e. Self Assessment Manual (Manual 118), Grand Junction Projects Office (internal document).

____________________, 1992f. Calibration Control Program for Measuring and Test Equipment and Measurement Standards (Manual 113), Grand Junction Projects Office (internal document).

____________________, 1993. Information Services Manual (Manual 105), Grand Junction Projects Office (internal document).

Appendix B

APPENDIX B

Methodology for Performing the Mann-Kendall Statistical Test

The Mann-Kendall Test is used for detecting trends in data sets over time. Although the test is nonparametric (does not require the data to be normally distributed), it is based on the same assumptions as parametric tests, such as observation independence (the observations should not exhibit seasonality or serial correlation). Because most quarterly or semiannually collected ground water data have seasonal variability, it is necessary to deseasonalize the data before performing the Mann-Kendall test. (Note: most quarterly or semiannually collected ground water data are not considered serially correlated, while monthly collected data often are.)

To deseasonalize the data set (Loftis 1990), arrange the data by season and year, as in Example B-1. Compute the mean and standard deviation for each season. Next subtract the mean from each variable within the season and divide by the standard deviation. Use these values for computing the Mann-Kendall test statistic.

Example B-1

Year	Spring	Summer	Fall	Winter
1980	5	4	5	4
1981	6	6	7	6
1982	7	8	8	7
1983	9	8	7	8
1984	11	10	10	9
$\Sigma=$	38	36	37	34
$n=$	5	5	5	5
$\bar{x}=$	7.6	7.2	7.4	6.8
$s=$	2.15	2.04	1.62	1.72

For example, to deseasonalize the 1980 spring value of 5, perform the following operations:

$$\frac{5 - 7.6}{2.15} = -1.21$$

Do this for each of the variables in the above table; the resulting values will be used to compute the Mann-Kendall statistic.

The methodology for performing the Mann-Kendall test is described in the following text, which has been excerpted from Gilbert (1987), with permission from the publishers.

Note: Table A18 listing the rejection values of the Mann-Kendall statistic, S, is in Gilbert (1987) or Kendall (1975). Critical values of Z are in standard normal tables within most statistical texts. Although Gilbert (1987) states that the normal approximation test may be used when n is greater than 40, Kendall (1975) and more recent authors (Loftis 1990) state that the normal approximation test may be used when n is greater than or equal to 10, unless there are many tied data values.

REFERENCES FOR APPENDIX B

Clark, C., and B. A. Berven, 1984. Results of the Groundwater Monitoring Program Performed at the Former St. Louis Airport Storage Site For the Period of January 1981 through January 1983. National Technical Information Service, Springfield, VA., ORNL/TM-8879.

Gilbert, R. O., 1987. *Statistical Methods for Environmental Pollution Monitoring*, Van Nostrand Reinhold Company, New York, NY.

Hirsch, R. M., J. R. Slack, and R. A. Smith, 1982. Techniques of trend analysis for monthly water quality data, *Water Resources Research* 18:107- 121.

Hollander, M., and D. A. Wolfe, 1973. *Nonparametric Statistical Methods*. Wiley, New York.

Kendall, M. G., 1975. *Rank Correlation Methods*, 4th Ed. Charles Griffin, London.

Loftis, J. C., 1990. Personal Communication, Colorado State University, Fort Collins, Colorado.

Mann, H. B., 1945. Non-Parametric tests against trend, *Econometrica* 13:245-259.

Sen, P. K., 1968b. Estimates of the regression coefficient based on Kendall's tau, *Journal of the American Statistical Association* 67:215-216.

Theil, H., 1950. A rank-invariant method of linear and polynomial regression analysis, Part 3, in *Proceedings of Koninalijke Nederlandse Akademie van Wetenschatpen* A 53:1397-1412.

van Belle, G., and J. P. Hughes, 1984. Nonparametric tests for trend in water quality, *Water Resources Research* 20:127-136.

CHAPTER 16

MANN-KENDALL TEST

(excerpted from *Statistical Methods for Environmental Pollution Monitoring*, by R. O. Gilbert, 1987)

16.3.3 Intervention Analysis and Box-Jenkins Models

If a long time sequence of equally spaced data is available, intervention analysis may be used to detect changes in average level resulting from a natural or man-induced intervention in the process. This approach, developed by Box and Tiao (1975), is a generalization of the autoregressive integrated moving-average (ARIMA) time series models described by Box and Jenkins (1976). Lettenmaier and Murray (1977) and Lettenmaier (1978) study the power of the method to detect trends. They emphasize the design of sampling plans to detect impacts from polluting facilities. Examples of its use are in Hipel et al. (1975) and Roy and Pellerin (1982).

Box-Jenkins modeling techniques are powerful tools for the analysis of time series data. McMichael and Hunter (1972) give a good introduction to Box-Jenkins modeling of environmental data, using both deterministic and stochastic components to forecast temperature flow in the Ohio River. Fuller and Tsokos (1971) develop models to forecast dissolved oxygen in a stream. Carlson, MacCormick, and Watts (1970) and McKerchar and Delleur (1974) fit Box-Jenkins models to monthly river flows. Hsu and Hunter (1976) analyze annual series of air pollution SO_2 concentrations. McCollister and Wilson (1975) forecast daily maximum and hourly average total oxidant and carbon monoxide concentrations in the Los Angeles Basin. Hipel, McLeod, and Lennox (1977*a*, 1977*b*) illustrate improved Box-Jenkins techniques to simplify model construction. Reinsel et al. (1981*a*, 1981*b*) use Box-Jenkins models to detect trends in stratospheric ozone data. Two introductory textbooks are McCleary and Hay (1980) and Chatfield (1984). Box and Jenkins (1976) is recommended reading for all users of the method.

Disadvantages of Box-Jenkins methods are discussed by Montgomery and Johnson (1976). At least 50 and preferably 100 or more data collected at equal (or approximately equal) time intervals are needed. When the purpose is forecasting, we must assume the developed model applies to the future. Missing data or data reported as trace or less-than values can prevent the use of Box-Jenkins methods. Finally, the modeling process is often nontrivial, with a considerable investment in time and resources required to build a satisfactory model. Fortunately, there are several packages of statistical programs that contain codes for developing time series models, including Minitab (Ryan, Joiner, and Ryan 1982), SPSS (1985), BMDP (1983), and SAS (1985). Codes for personal computers are also becoming available.

16.4 MANN-KENDALL TEST

In this section we discuss the nonparametric Mann-Kendall test for trend (Mann, 1945; Kendall, 1975). This procedure is particularly useful since missing values are allowed and the data need not conform to any particular distribution. Also, data reported as trace or less than the detection limit can be used (if it is acceptable in the context of the population being ampled) by assigning them a common value that is smaller than the smallest measured value in the data set. This approach can be used because the Mann-Kendall test (and the seasonal Kendall test in Chapter 17) use only the relative magnitudes of the data rather than their measured values. We note that the Mann-Kendall test can be viewed as a nonparametric test for zero slope of the linear regression of time-ordered data versus time, as illustrated by Hollander and Wolfe (1973, p. 201).

16.4.1 Number of Data 40 or Less

If n is 40 or less, the procedure in this section may be used. When n exceeds 40, use the normal approximation test in Section 16.4.2. We begin by considering the case where only one datum per time period is taken, where a time period may be a day, week, month, and so on. The case of multiple data values per time period is discussed in Section 16.4.3.

The first step is to list the data in the order in which they were collected over time: $x_1, x_2, \ldots, x_n$, where x_i is the datum at time i. Then determine the sign of all $n(n-1)/2$ possible differences $x_j - x_k$, where $j > k$. These differences are $x_2 - x_1, x_3 - x_1, \ldots, x_n - x_1, x_3 - x_2, x_4 - x_2, \ldots, x_n - x_{n-2}, x_n - x_{n-1}$. A convenient way of arranging the calculations is shown in Table 16.1.

Let $\text{sgn}(x_j - x_k)$ be an indicator function that takes on the values 1, 0, or -1 according to the sign of $x_j - x_k$:

$$\begin{aligned} \text{sgn}(x_j - x_k) &= 1 \quad \text{if } x_j - x_k > 0 \\ &= 0 \quad \text{if } x_j - x_k = 0 \\ &= -1 \quad \text{if } x_j - x_k < 0 \end{aligned} \tag{16.1}$$

Then compute the Mann-Kendall statistic

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} \text{sgn}(x_j - x_k) \tag{16.2}$$

which is the number of positive differences minus the number of negative differences. These differences are easily obtained from the last two columns of Table 16.1. If S is a large positive number, measurements taken later in time tend to be larger than those taken earlier. Similarly, if S is a large negative number, measurements taken later in time tend to be smaller. If n is large, the computer code in Appendix B may be used to compute S. This code also computes the tests for trend discussed in Chapter 17.

Suppose we want to test the null hypothesis, H_0, of no trend against the alternative hypothesis, H_A, of an upward trend. Then H_0 is rejected in favor of H_A if S is positive and if the probability value in Table A18 corresponding to the computed S is less than the a priori specified α significance level of the test. Similarly, to test H_0 against the alternative hypothesis H_A of a downward trend, reject H_0 and accept H_A if S is negative and if the probability value in the table corresponding to the absolute value of S is less than the a priori specified α value. If a two-tailed test is desired, that is, if we want to detect either an upward or downward trend, the tabled probability level corresponding to the absolute value of S is doubled and H_0 is rejected if that doubled value is less than the a priori α level.

EXAMPLE 16.1

We wish to test the null hypothesis H_0, of no trend versus the alternative hypothesis, H_A, of an upward trend at the $\alpha = 0.10$

Table 16.1 Differences in Data Values Needed for Computing the Mann-Kendall Statistic S to Test for Trend

Data Values Listed in the Order Collected Over Time							*No. of + Signs*	*No. of − Signs*
x_1	x_2	x_3	x_4	$\cdots$	x_{n-1}	x_n		
	$x_2 - x_1$	$x_3 - x_1$	$x_4 - x_1$	$\cdots$	$x_{n-1} - x_1$	$x_n - x_1$		
		$x_3 - x_2$	$x_4 - x_2$	$\cdots$	$x_{n-1} - x_2$	$x_n - x_2$		
			$x_4 - x_3$	$\cdots$	$x_{n-1} - x_3$	$x_n - x_3$		
				$\ddots$	$\vdots$	$\vdots$		
					$x_{n-1} - x_{n-2}$	$x_n - x_{n-2}$		
						$x_n - x_{n-1}$		
						$S =$	$\binom{\text{sum of}}{\text{+ signs}}$ +	$\binom{\text{sum of}}{\text{− signs}}$

Table 16.2 Computation of the Mann-Kendall Trend Statistic S for the Time Ordered Data Sequence 10, 15, 14, 20

Time	*1*	*2*	*3*	*4*		*No. of +*		*No. of −*
Data	*10*	*15*	*14*	*20*		*Signs*		*Signs*
		15 − 10	14 − 10	20 − 10		3		0
			14 − 15	20 − 15		1		1
				20 − 14		1		0
				S	=	5	−	1 = 4

significance level. For ease of illustration suppose only 4 measurements are collected in the following order over time or along a line in space: 10, 15, 14, and 20. There are 6 differences to consider: 15 − 10, 14 − 10, 20 − 10, 14 − 15, 20 − 15, and 20 − 14. Using Eqs. 16.1 and 16.2, we obtain $S = +1 + 1 + 1 - 1 + 1 + 1 = +4$, as illustrated in Table 16.2. (Note that the sign, not the magnitude of the difference is used.) From Table A18 we find for $n = 4$ that the tabled probability for $S = +4$ is 0.167. This number is the probability of obtaining a value of S equal to +4 or larger when $n = 4$ and when no upward trend is present. Since this value is greater than 0.10, we cannot reject H_0.

If the data sequence had been 18, 20, 23, 35, then $S = +6$, and the tabled probability is 0.042. Since this value is less than 0.10, we reject H_0 and accept the alternative hypothesis of an upward trend.

Table A18 gives probability values only for $n \leq 10$. An extension of this table up to $n = 40$ is given in Table A.21 in Hollander and Wolfe (1973).

16.4.2 Number of Data Greater Than 40

When n is greater than 40, the normal approximation test described in this section is used. Actually, Kendall (1975, p. 55) indicates that this method may be used for n as small as 10 unless there are many tied data values. The test procedure is to first compute S using Eq. 16.2 as described before. Then compute the variance of S by the following equation, which takes into account that ties may be present:

$$\mathrm{VAR}(S) = \frac{1}{18}\left[n(n-1)(2n+5) - \sum_{p=1}^{g} t_p(t_p - 1)(2t_p + 5)\right] \qquad \textbf{16.3}$$

where g is the number of tied groups and t_p is the number of data in the pth group. For example, in the sequence {23, 24, trace, 6, trace, 24, 24, trace, 23} we have $g = 3$, $t_1 = 2$ for the tied value 23, $t_2 = 3$ for the tied value 24, and $t_3 = 3$ for the three trace values (considered to be of equal but unknown value less than 6).

Then S and VAR(S) are used to compute the test statistic Z as follows:

$$\begin{aligned} Z &= \frac{S-1}{[\mathrm{VAR}(S)]^{1/2}} && \text{if } S > 0 \\ &= 0 && \text{if } S = 0 \\ &= \frac{S+1}{[\mathrm{VAR}(S)]^{1/2}} && \text{if } S < 0 \end{aligned} \qquad \textbf{16.4}$$

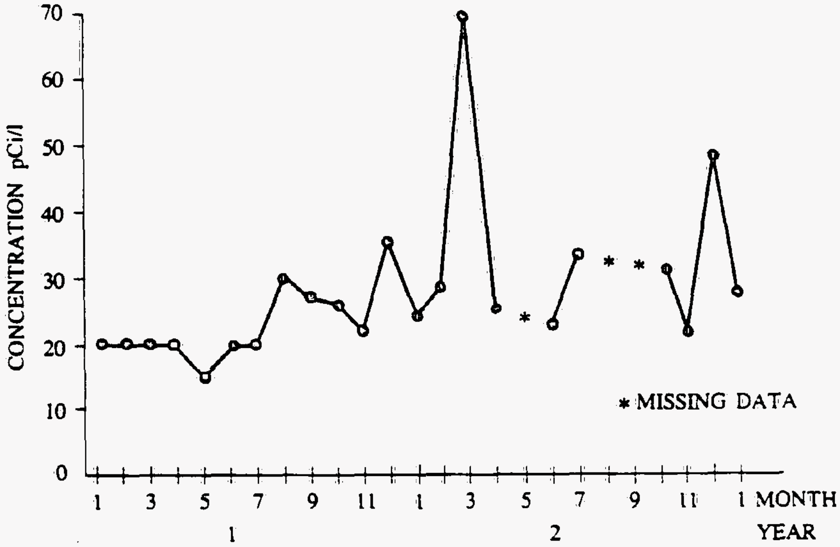


Figure 16.2 Concentrations of ^{238}U in ground water in well E at the former St. Louis Airport storage site for January 1981 through January 1983 (after Clark and Berven, 1984).

A positive (negative) value of Z indicates an upward (downward) trend. If the null hypothesis, H_0, of no trend is true, the statistic Z has a standard normal distribution, and hence we use Table A1 to decide whether to reject H_0. To test for either upward or downward trend (a two-tailed test) at the α level of significance, H_0 is rejected if the absolute value of Z is greater than $Z_{1-\alpha/2}$, where $Z_{1-\alpha/2}$ is obtained from Table A1. If the alternative hypothesis is for an upward trend (a one-tailed test), H_0 is rejected if Z (Eq. 16.4) is greater than $Z_{1-\alpha}$. We reject H_0 in favor of the alternative hypothesis of a downward trend if Z is negative and the absolute value of Z is greater than $Z_{1-\alpha/2}$. Kendall (1975) indicates that using the standard normal tables (Table A1) to judge the statistical significance of the Z test will probably introduce little error as long as $n \geq 10$ unless there are many groups of ties and many ties within groups.

EXAMPLE 16.2

Figure 16.2 is a plot of $n = 22$ monthly ^{238}U concentrations $x_1, x_2, x_3, \ldots, x_{22}$ obtained from a groundwater monitoring well from January 1981 through January 1983 (reported in Clark and Berven, 1984). We use the Mann-Kendall procedure to test the null hypothesis at the $\alpha = 0.05$ level that there is no trend in ^{238}U groundwater concentrations at this well over this 2-year period. The alternative hypothesis is that an upward trend is present.

There are $n(n-1)/2 = 22(21)/2 = 231$ differences to examine for their sign. The computer code in Appendix B was used to obtain S and Z (Eqs. 16.2 and 16.4). We find that $S = +108$. Since there are 6 occurrences of the value 20 and 2 occurrences of both 23 and 30, we have $g = 3$, $t_1 = 6$, and $t_2 = t_3 = 2$. Hence, Eq. 16.3 gives

$$\begin{aligned}\mathrm{VAR}(S) &= \tfrac{1}{18}\,[22(21)(44 + 5)\\ &\quad - 6(5)(12 + 5) - 2(1)(4 + 5) - 2(1)(4 + 5)]\\ &= 1227.33\end{aligned}$$

or $[\mathrm{VAR}(S)]^{1/2} = 35.0$. Therefore, since $S > 0$, Eq. 16.4 gives $Z = (108 - 1)/35.0 = 3.1$. From Table A1 we find $Z_{0.95} = 1.645$. Since Z exceeds 1.645, we reject H_0 and accept the alternative hypothesis of an upward trend. We note that the three missing values in Figure 16.2 do not enter into the calculations in any way. They are simply ignored and constitute a regrettable loss of information for evaluating the presence of trend.

16.4.3 Multiple Observations per Time Period

When there are multiple observations per time period, there are two ways to proceed. First, we could compute a summary statistic, such as the median, for each time period and apply the Mann-Kendall test to the medians. An alternative approach is to consider the $n_i \geq 1$ multiple observations at time i (or time period i) as ties in the time index. For this latter case the statistic S is still computed by Eq. 16.2, where n is now the sum of the n_i, that is, the total number of observations rather than the number of time periods. The differences between data obtained at the same time are given the score 0 no matter what the data values may be, since they are tied in the time index.

When there are multiple observations per time period, the variance of S is computed by the following equation, which accounts for ties in the time index:

$$\begin{aligned}\mathrm{VAR}(S) = \frac{1}{18}\Bigg[& n(n-1)(2n+5) - \sum_{p=1}^{g} t_p(t_p-1)(2t_p+5)\\ & - \sum_{q=1}^{h} u_q(u_q-1)(2u_q+5)\Bigg]\\ & + \frac{\sum_{p=1}^{g} t_p(t_p-1)(t_p-2)\sum_{q=1}^{h} u_q(u_q-1)(u_q-2)}{9n(n-1)(n-2)}\\ & + \frac{\sum_{p=1}^{g} t_p(t_p-1)\sum_{q=1}^{h} u_q(u_q-1)}{2n(n-1)}\end{aligned} \qquad \textbf{16.5}$$

where g and t_p are as defined following Eq. 16.3, h is the number of time periods that contain multiple data, and u_q is the number of multiple data in the qth time period. Equation 16.5 reduces to Eq. 16.3 when there is one observation per time period.

Equations 16.3 and 16.5 assume all data are independent and, hence, uncorrelated. If observations taken during the same time period are highly correlated, it may be preferable to apply the Mann-Kendall test to the medians of the data in each time period rather than use Eq. 16.5 in Eq. 16.4.

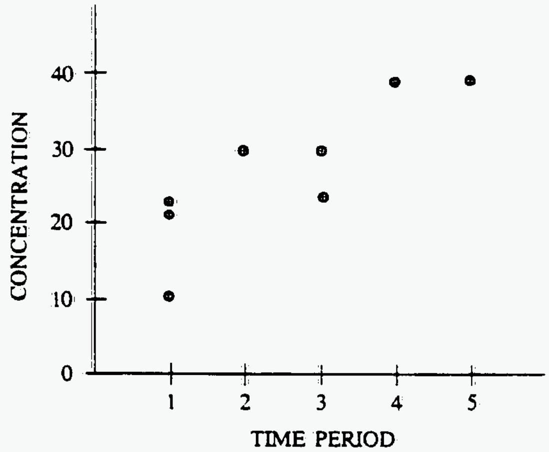


Figure 16.3 An artificial data set to illustrate the Mann-Kendall test for trend when ties in both the data and time are present.

EXAMPLE 16.3

To illustrate the computation of S and VAR(S), consider the following artificial data set:

(concentration, time period)

= (10, 1), (22, 1), (21, 1), (30, 2), (22, 3), (30, 3), (40, 4), (40, 5)

as plotted in Figure 16.3. There are 5 time periods and $n = 8$ data. To illustrate computing S, we lay out the data as follows:

Time Period :	1	1	1	2	3	3	4	5
Data :	10	22	21	30	22	30	40	40

We shall test at the $\alpha = 0.05$ level the null hypothesis, H_0, of no trend versus the alternative hypothesis, H_A, of an upward trend, a one-tailed test.

Now, look at all 8(7)/2 = 28 possible data pairs, remembering to give a score of 0 to the 4 pairs within the same time index. The differences are shown in Table 16.3. Ignore the magnitudes of the differences, and sum the number of positive and negative signs to obtain $S = 19$. It is clear from Figure 16.3 that there are $g = 3$ tied data groups (22, 30, and 40) with $t_1 = t_2 = t_3 = 2$. Also, there are $h = 2$ time index ties (times 1 and 3) with $u_1 = 3$ and $u_2 = 2$. Hence, Eq. 16.5 gives

$$\begin{aligned}\mathrm{VAR}(S) &= \frac{1}{18}[8(7)(16+5) - 3(2)(1)(4+5) - 3(2)(6+5) \\ &\quad - 2(1)(4+5)] + 0 + \frac{[3(2)(1)][3(2)+2(1)]}{2(8)(7)} \\ &= 58.1\end{aligned}$$

or $[\mathrm{VAR}(S)]^{1/2} = 7.6$. Hence, Eq. 16.4 gives $Z = (19 - 1)/7.6$

Table 16.3 Illustration of Computing S for Example 16.3

Time Period / *Data*	*1* / *10*	*1* / *22*	*1* / *21*	*2* / *30*	*3* / *22*	*3* / *30*	*4* / *40*	*5* / *40*	*Sum of +* / *Signs*	*Sum of −* / *Signs*
		NC	NC	+20	+12	+20	+30	+30	5	0
			NC	+8	0	+8	+18	+18	4	0
				+9	+1	+9	+19	+19	5	0
					−8	0	+10	+10	2	1
						NC	+18	+18	2	0
							+10	+10	2	0
								0	0	0
								S	= 20	−1
									= 19	

NC = Not computed since both data values are within the same time period.

= 2.4. Referring to Table A1, we find $Z_{0.95} = 1.645$. Since $Z > 1.645$, reject H_0 and accept the alternative hypothesis of an upward trend.

16.4.4 Homogeneity of Stations

Thus far only one station has been considered. If data over time have been collected at $M > 1$ stations, we have data as displayed in Table 16.4 (assuming one datum per sampling period). The Mann-Kendall test may be computed for each station. Also, an estimate of the magnitude of the trend at each station can be obtained using Sen's (1968*b*) procedure, as described in Section 16.5.

When data are collected at several stations within a region or basin, there may be interest in making a basin-wide statement about trends. A general statement about the presence or absence of monotonic trends will be meaningful if the trends at all stations are in the same direction—that is, all upward or all downward. Time plots of the data at each station, preferably on the same graph to make visual comparison easier, may indicate when basin-wide statements are possible. In many situations an objective testing method will be needed to help make this decision. In this section we discuss a method for doing this that

Table 16.4 Data Collected over Time at Multiple Stations

		Station 1				. . .		*Station M*			
		Sampling Time				. . .		*Sampling Time*			
		1	*2*		*K*			*1*	*2*		*K*
Year	1	x_{111}	x_{211}	. . .	x_{K11}	. . .	1	x_{11M}	x_{21M}	. . .	x_{K1M}
	2	x_{121}	x_{221}	. . .	x_{K21}	. . .	2	x_{12M}	x_{22M}	. . .	x_{K2M}
	⋮						⋮				
	L	x_{1L1}	x_{2L1}	. . .	x_{KL1}	. . .	L	x_{1LM}	x_{2LM}	. . .	x_{KLM}
Mann-Kendall Test		S_1				. . .		S_M			
		Z_1				. . .		Z_M			

M = number of stations
K = number of sampling times per year
L = number of years
x_{ilj} = datum for the ith sampling time in the lth year at the jth station

makes use of the Mann-Kendall statistic computed for each station. This procedure was originally proposed by van Belle and Hughes (1984) to test for homogeneity of trends between seasons (a test discussed in Chapter 17).

To test for homogeneity of trend direction at multiple stations, compute the homogeneity chi-square statistic, χ^2_{homog}, where

$$\chi^2_{\text{homog}} = \chi^2_{\text{total}} - \chi^2_{\text{trend}} = \sum_{j=1}^{M} Z_j^2 - M\bar{Z}^2 \qquad 16.6$$

$$Z_j = \frac{S_j}{[\text{VAR}(S_j)]^{1/2}} \qquad 16.7$$

S_j is the Mann-Kendall trend statistic for the jth station,

and $\bar{Z} = \frac{1}{M}\sum_{j=1}^{M} Z_j$

If the trend at each station is in the same direction, then χ^2_{homog} has a chi-square distribution with $M - 1$ degrees of freedom (df). This distribution is given in Table A19. To test for trend homogeneity between stations at the α significance level, we refer our calculated value of χ^2_{homog} to the α critical value in Table A19 in the row with $M - 1$ df. If χ^2_{homog} exceeds this critical value, we reject the H_0 of homogeneous station trends. In that case no regional-wide statements should be made about trend direction. However, a Mann-Kendall test for trend at each station may be used. If χ^2_{homog} does not exceed the α critical level in Table A19, then the statistic $\chi^2_{\text{trend}} = M\bar{Z}^2$ is referred to the chi-square distribution with 1 df to test the null hypothesis H_0 that the (common) trend direction is significantly different from zero.

The validity of these chi-square tests depends on each of the Z_j values (Eq. 16.7) having a standard normal distribution. Based on results in Kendall (1975), this implies that the number of data (over time) for each station should exceed 10. Also, the validity of the tests requires that the Z_j be independent. This requirement means that the data from different stations must be uncorrelated. We note that the Mann-Kendall test and the chi-square tests given in this section may be computed even when the number of sampling times, K, varies from year to year and when there are multiple data collected per sampling time at one or more times.

EXAMPLE 16.4

We consider a simple case to illustrate computations. Suppose the following data are obtained:

	Time				
	1	*2*	*3*	*4*	*5*
Station 1	10	12	11	15	18
Station 2	10	9	10	8	9

We wish to test for homogeneous trend direction at the $M = 2$ stations at the $\alpha = 0.05$ significance level. Equation 16.2 gives $S_1 = 1 + 1 + 1 + 1 - 1 + 1 + 1 + 1 + 1 + 1 = +9 - 1 =$

8 and $S_2 = -1 + 0 - 1 - 1 + 1 - 1 + 0 - 1 - 1 + 1 = 2 - 6 = -4$. Equation 16.3 gives

$$\mathrm{VAR}(S_1) = \frac{5(4)(15)}{18} = 16.667 \quad \text{and} \quad \mathrm{VAR}(S_2)$$

$$= \frac{[5(4)(15) - 2(1)(9) - 2(1)(9)]}{18} = 14.667$$

Therefore Eq. 16.4 gives

$$Z_1 = \frac{7}{(16.667)^{1/2}} = 1.71 \quad \text{and} \quad Z_2 = \frac{-3}{(14.667)^{1/2}} = -0.783$$

Thus

$$\chi^2_{\text{homog}} = 1.71^2 + (-0.783)^2 - 2\left(\frac{1.71 - 0.783}{2}\right)^2 = 3.1$$

Referring to the chi-square tables with $M - 1 = 1$ df, we find the $\alpha = 0.05$ level critical value is 3.84. Since $\chi^2_{\text{homog}} < 3.84$, we cannot reject the null hypothesis of homogeneous trend direction over time at the 2 stations. Hence, an overall test of trend using the statistic χ^2_{trend} can be made. [Note that the critical value 3.84 is only approximate (somewhat too small), since the number of data at both stations is less than 10.] $\chi^2_{\text{trend}} = M\bar{Z}^2 = 2(0.2148) = 0.43$. Since $0.43 < 3.84$, we cannot reject the null hypothesis of no trend at the 2 stations.

We may test for trend at each station using the Mann-Kendall test by referring $S_1 = 8$ and $S_2 = -4$ to Table A18. The tabled value for $S_1 = 8$ when $n = 5$ is 0.042. Doubling this value to give a two-tailed test gives 0.084, which is greater than our prespecified $\alpha = 0.05$. Hence, we cannot reject H_0 of no trend for station 1 at the $\alpha = 0.05$ level. The tabled value for $S_2 = -4$ when $n = 5$ is 0.242. Since $0.484 > 0.05$, we cannot reject H_0 of no trend for station 2. These results are consistent with the χ^2_{trend} test before. Note, however, that station 1 still appears to be increasing over time, and the reader may confirm it is significant at the $\alpha = 0.10$ level. This result suggests that this station be carefully watched in the future.

16.5 SEN'S NONPARAMETRIC ESTIMATOR OF SLOPE

As noted in Section 16.3.2, if a linear trend is present, the true slope (change per unit time) may be estimated by computing the least squares estimate of the slope, *b*, by linear regression methods. However, *b* computed in this way can deviate greatly from the true slope if there are gross errors or outliers in the data. This section shows how to estimate the true slope at a sampling station by using a simple nonparametric procedure developed by Sen (1968b). His procedure is an extension of a test by Theil (1950), which is illustrated by Hollander and Wolfe (1973, p. 205). Sen's method is not greatly affected by gross data errors or outliers, and it can be computed when data are missing. Sen's estimator is closely related to the Mann-Kendall test, as illustrated in the following paragraphs. The computer code in Appendix B computes Sen's estimator.

First, compute the N' slope estimates, Q, for each station:

$$Q = \frac{x_{i'} - x_i}{i' - i} \qquad 16.8$$

where $x_{i'}$ and x_i are data values at times (or during time periods) i' and i, respectively, and where $i' > i$; N' is the number of data pairs for which $i' > i$. The median of these N' values of Q is Sen's estimator of slope. If there is only one datum in each time period, then $N' = n(n-1)/2$, where n is the number of time periods. If there are multiple observations in one or more time periods, then $N' < n(n-1)/2$, where n is now the total number of observations, not time periods, since Eq. 16.8 cannot be computed with two data from the same time period, that is, when $i' = i$. If an x_i is below the detection limit, one half the detection limit may be used for x_i.

The median of the N' slope estimates is obtained in the usual way, as discussed in Section 13.3.1. That is, the N' values of Q are ranked from smallest to largest (denote the ranked values by $Q_{[1]} \le Q_{[2]} \le \cdots \le Q_{[N'-1]} \le Q_{[N']}$) and we compute

$$\begin{aligned}\text{Sen's estimator} &= \text{median slope} \\ &= Q_{[(N'+1)/2]} && \text{if } N' \text{ is odd} \\ &= \tfrac{1}{2}\left(Q_{[N'/2]} + Q_{[(N'+2)/2]}\right) && \text{if } N' \text{ is even}\end{aligned} \qquad 16.9$$

A $100(1-\alpha)\%$ two-sided confidence interval about the true slope may be obtained by the nonparametric technique given by Sen (1968b). We give here a simpler procedure, based on the normal distribution, that is valid for n as small as 10 unless there are many ties. This procedure is a generalization of that given by Hollander and Wolfe (1973, p. 207) when ties and/or multiple observations per time period are present.

1. Choose the desired confidence coefficient α and find $Z_{1-\alpha/2}$ in Table A1.
2. Compute $C_\alpha = Z_{1-\alpha/2}[\mathrm{VAR}(S)]^{1/2}$, where VAR($S$) is computed from Eqs. 16.3 or 16.5. The latter equation is used if there are multiple observations per time period.
3. Compute $M_1 = (N' - C_\alpha)/2$ and $M_2 = (N' + C_\alpha)/2$.
4. The lower and upper limits of the confidence interval are the M_1th largest and $(M_2 + 1)$th largest of the N' ordered slope estimates, respectively.

EXAMPLE 16.5

We use the data set in Example 16.3 to illustrate Sen's procedure. Recall that the data are

Time Period	1	1	1	2	3	3	4	5
Data	10	22	21	30	22	30	40	40

There are $N' = 24$ pairs for which $i' > i$. The values of individual

Table 16.5 Illustration of Computing an Estimate of Trend Slope Using Sen's (1968*b*) Nonparametric Procedure (for Example 16.5). Tabled Values Are Individual Slope Estimates, *Q*

Time Period	*1*	*1*	*1*	*2*	*3*	*3*	*4*	*5*
Data	*10*	*22*	*21*	*30*	*22*	*30*	*40*	*40*
		NC	NC	+20	+6	+10	+10	+7.5
			NC	+8	0	+4	+6	+4.5
				+9	+0.5	+4.5	+6.33	+4.75
					−8	0	+5	+3.33
						NC	+18	+9
							+10	+5
								0

NC = Cannot be computed since both data values are within the same time period.

slope estimates Q for these pairs are obtained by dividing the differences in Table 16.3 by $i' - i$. The 24 Q values are given in Table 16.5.

Ranking these Q values from smallest to largest gives

−8, 0, 0, 0, 0.5, 3.33, 4, 4.5, 4.5, 4.75, 5, 5, 6, 6, 6.33, 7.5, 8, 9, 9, 10, 10, 10, 18, 20

Since $N' = 24$ is even, the median of these Q values is the average of the 12th and 13th largest values (by Eq. 16.8), which is 5.5, the Sen estimate of the true slope. That is, the average (median) change is estimated to be 5.5 units per time period.

A 90% confidence interval about the true slope is obtaied as follows. From Table A1 we find $Z_{0.95} = 1.645$. Hence,

$$C_\alpha = 1.645[\mathrm{VAR}(S)]^{1/2} = 1.645[58.1]^{1/2} = 12.54$$

where the value for VAR(S) was obtained from Example 16.3. Since $N' = 24$, we have $M_1 = (24 - 12.54)/2 = 5.73$ and $M_2 + 1 = (24 + 12.54)/2 + 1 = 19.27$. From the list of 24 ordered slopes given earlier, the lower limit is found to be 2.6 by interpolating between the 5th and 6th largest values. The upper limit is similarly found to be 9.3 by interpolating between the 19th and 20th largest values.

16.6 CASE STUDY

This section illustrates the procedures presented in this chapter for evaluating trends. The computer program in Appendix B is used on the hypothetical data listed in Table 16.6 and plotted in Figure 16.4. These data, generated on a computer, represent measurements collected monthly at two stations for 48 consecutive months. The model for station 1 is $x_{il1} = \exp[0.83e_{il} - 0.35] - 1.0$, where x_{il1} is the datum for month i in year l at station 1. The model used at station 2 was $x_{il2} = \exp[0.83e_{il} - 0.35] - 1.0 + 0.40(i/12 + l)$. For both stations the measurement errors e_{il} were generated to have mean 0 and variance 1. The data for station 1 are lognormally distributed with no trend.

Table 16.6 Simulated Monthly Data at Two Stations over a Four-Year Period

NUMBER OF YEARS = 4
NUMBER OF STATIONS = 2

STATION 1	NUMBER OF DATA POINTS 48		STATION 2	NUMBER OF DATA POINTS 48	
YEAR	MONTH	STATION 1	YEAR	MONTH	STATION 2
1	1	6.00	1	1	5.09
1	2	5.41	1	2	5.07
1	3	4.58	1	3	4.93
1	4	4.34	1	4	4.94
1	5	4.77	1	5	5.15
1	6	4.54	1	6	11.82
1	7	4.50	1	7	5.48
1	8	5.02	1	8	5.18
1	9	4.38	1	9	5.79
1	10	4.27	1	10	5.11
1	11	4.33	1	11	5.10
1	12	4.33	1	12	5.94
2	13	5.00	2	13	6.91
2	14	5.02	2	14	7.11
2	15	4.14	2	15	5.40
2	16	5.16	2	16	6.77
2	17	6.33	2	17	5.35
2	18	5.49	2	18	6.04
2	19	4.54	2	19	5.45
2	20	6.62	2	20	6.95
2	21	4.64	2	21	5.54
2	22	4.45	2	22	5.71
2	23	4.57	2	23	6.14
2	24	4.09	2	24	7.13
3	25	5.06	3	25	5.80
3	26	4.83	3	26	5.91
3	27	4.92	3	27	5.88
3	28	6.02	3	28	7.21
3	29	4.77	3	29	8.29
3	30	5.03	3	30	6.00
3	31	7.15	3	31	6.28
3	32	4.30	3	32	5.69
3	33	4.15	3	33	6.52
3	34	5.13	3	34	6.27
3	35	5.28	3	35	6.46
3	36	4.31	3	36	6.94
4	37	6.53	4	37	6.28
4	38	5.11	4	38	6.74
4	39	4.31	4	39	6.91
4	40	4.64	4	40	7.81
4	41	4.87	4	41	6.53
4	42	4.89	4	42	6.26
4	43	4.92	4	43	7.01
4	44	4.94	4	44	7.42
4	45	4.69	4	45	8.35
4	46	4.50	4	46	6.27
4	47	4.80	4	47	6.69
4	48	4.80	4	48	6.99

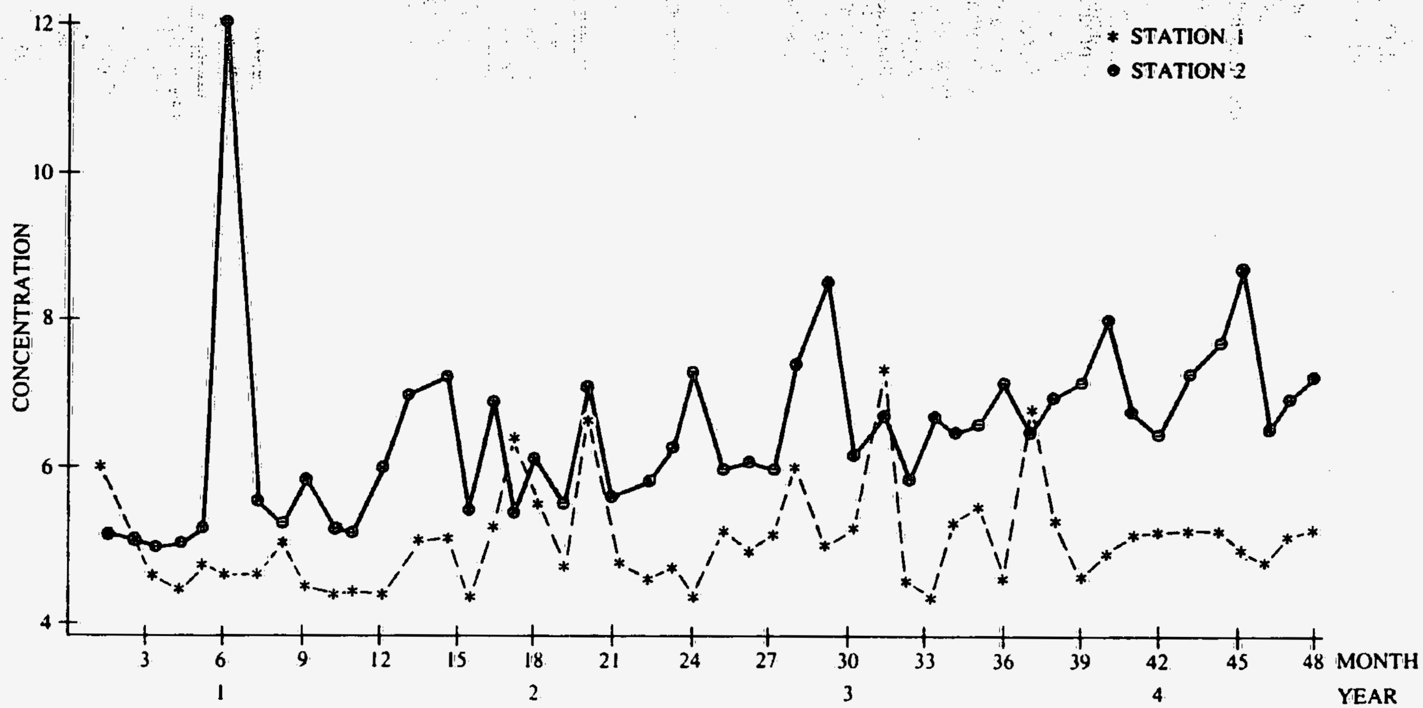


Figure 16.4 Data at two stations each month for four years. Data were simulated using the lognormal independent model given by Hirsch, Slack, and Smith (1982, Eq. 14b). Simulated data were obtained by D. W. Engel.

and the data for station 2 are lognormal with a trend of 0.4 units per year or 0.0333 units per month. These models were among those used by Hirsch, Slack, and Smith (1982) to evaluate the power of the seasonal Kendall test for trend, a test we discuss in Chapter 17.

The results obtained from the computer code in Appendix B are shown in Table 16.7. The first step is to decide whether the two stations have trends in the same direction. In this example we know it is not so, since one station has a trend and the other does not. But in practice this a priori information will not be available.

Table 16.7 shows that the chi-square test of homogeneity (Eq. 16.6) is highly significant (χ^2_{homog} = 10.0; computed significance level of 0.002). Hence, we ignore the chi-square test for trend that is automatically computed by the program and turn instead to the Mann-Kendall test results for each station. This test for station 1 is nonsignificant (*P* value of 0.70), indicating no strong evidence for trends, but that for station 2 is highly significant. All of these test results agree with the true situation. Sen's estimates of slope are 0.002 and 0.041 per month for stations 1 and 2, whereas the true values are 0.0 and 0.0333, respectively. The computer code computes $100(1 - \alpha)\%$ confidence limits for the true slope for α = 0.20, 0.10, 0.05, and 0.01. For this example the 95% confidence limits are −0.009 and 0.012 for station 1, and 0.030 and 0.050 for station 2.

The computer code allows one to split up the 48 observations at each station into meaningful groups that contain multiple observations. For instance, suppose

Table 16.7 Chi-Square Tests for Homogeneity of Trends at the Two Stations, and Mann-Kendall Tests for Each Station

HOMOGENEITY TEST RESULTS

CHI-SQUARE STATISTICS		df	PROB. OF A LARGER VALUE	
TOTAL	23.97558	2	0.000	
HOMOGENEITY	10.03524	1	0.002	← Trend not equal at the 2 stations
TREND	13.94034	1	0.000	← Not meaningful

STATION	SEASON	MANN-KENDALL S STATISTIC	Z STATISTIC	n	PROB. OF EXCEEDING THE ABSOLUTE VALUE OF THE Z STATISTIC (TWO-TAILED TEST) IF n > 10
1	1	45.00	0.39121	48	0.696
2	1	549.00	4.87122	48	0.000

SEN SLOPE CONFIDENCE INTERVALS

STATION	SEASON	ALPHA	LOWER LIMIT	SLOPE	UPPER LIMIT
1	1	0.010	-0.013	0.002	0.016
		0.050	-0.009	0.002	0.012
		0.100	-0.007	0.002	0.011
		0.200	-0.005	0.002	0.009
2	1	0.010	0.026	0.041	0.054
		0.050	0.030	0.041	0.050
		0.100	0.032	0.041	0.048
		0.200	0.034	0.041	0.046

Table 16.8 Analyses of the Data in Table 16.6 Considering the Data as Twelve Multiple Observations in Each of Four Years

NUMBER OF YEARS = 4
NUMBER OF SEASONS = 1
NUMBER OF STATIONS = 2

HOMOGENEITY TEST RESULTS

SOURCE	CHI-SQUARE	df	PROB. OF A LARGER VALUE
TOTAL	21.45468	2	0.000
HOMOGENEITY	5.79732	1	0.016
TREND	15.65736	1	0.000

STATION	SEASON	MANN-KENDALL S STATISTIC	Z STATISTIC	n	PROB. OF EXCEEDING THE ABSOLUTE VALUE OF THE Z STATISTIC (TWO-TAILED TEST) IF n > 10
1	1	119.00	1.08623	48	0.277
2	1	489.00	4.49132	48	0.000

SEN SLOPE CONFIDENCE INTERVALS

STATION	SEASON	ALPHA	LOWER LIMIT	SLOPE	UPPER LIMIT
1	1	0.010	-0.120	0.080	0.225
		0.050	-0.065	0.080	0.190
		0.100	-0.037	0.080	0.176
		0.200	-0.014	0.080	0.153
2	1	0.010	0.290	0.467	0.670
		0.050	0.353	0.467	0.620
		0.100	0.370	0.467	0.600
		0.200	0.390	0.467	0.575

we regard the data in this example as 12 multiple data points in each of four years. Applying the code using this interpretation gives the results in Table 16.8.

The conclusions of the tests are the same as obtained in Table 16.7 when the data were considered as one time series of 48 single observations. However, this may not be the case with other data sets or groupings of multiple observations. Indeed, the Mann-Kendall test statistic Z for station 1 is larger in Table 16.8 than in Table 16.7, so that the test is closer to (falsely) indicating a significant trend when the data are grouped into years. For station 2 the Mann-Kendall test in Table 16.8 is smaller than in Table 16.7, indicating the test has less power to detect the trend actually present. The best strategy appears to be to not group data unnecessarily. The estimates of slope are now 0.080 and 0.467 per year, whereas the true values are 0.0 and 0.40, respectively.

16.7 SUMMARY

This chapter began by identifying types of trends and some of the complexities that arise when testing for trend. It also discussed graphical methods for detecting